ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

AN APPROACH FOR ENERGY EFFICIENCY AND SUSTAINABILITY IN EMERGENCY ARCHITECTURE: EVALUATION OF POST-DISASTER SHELTERS IN TURKEY

M.Sc. THESIS

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Department of Architecture
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İSTANBUL TEKNİK ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ

AFET MİMARLIĞINDA ENERJİ VERİMLİLİĞİ VE SÜRDÜRÜLEBİLİRLİK İÇİN BİR YAKLAŞIM: TÜRKİYE'DEKİ AFET SONRASI BARINAKLARININ DEĞERLENDİRİLMESİ

YÜKSEK LİSANS TEZİ

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Santiago BRUSADIN VIOLA, a **M.Sc.** student of ITU **Institute of Architecture** student ID **502111516**, successfully defended the **thesis** entitled **“AN APPROACH FOR ENERGY EFFICIENCY AND SUSTAINABILITY IN EMERGENCY ARCHITECTURE: EVALUATION OF POST-DISASTER SHELTERS IN TURKEY”** which he prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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FOREWORD

I would like to express my thanks to Prof. Dr. A. Zerrin Yılmaz who has played a key role in encouraging and coordinating this study. Her support and advice has been essential.

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June 2013 Santiago BRUSADIN

(Architect)

TABLE OF CONTENTS

Page

ABBREVIATIONS

BREEAM	**:** BRE Environmental Assessment Method
CM	: Centimeters
CCS	: Concrete Canvas Shelter
CO2	: Carbon dioxide
FEMA	: Federal Emergency Management Agency
GRRT	: Green Recovery and Reconstruction Toolkit
HVAC	: Heating, ventilation, and air conditioning
LEED	: Leadership in Energy and Environmental Design
NGO	: Non-governmental organization
M2	: Square meters
TRCS	: Turkish Red Crescent Society
USGBC	: United States Green Building Council

LIST OF TABLES

LIST OF FIGURES

AN APPROACH FOR ENERGY EFFICIENCY AND SUSTAINABILITY IN EMERGENCY ARCHITECTURE: EVALUATION OF POST-DISASTER HOUSING IN TURKEY

SUMMARY

Natural and human disasters such as earthquakes and military conflicts cause every year extensive loss of lives, hamper development and bring economic losses, particularly in developing countries, where many people reside in buildings and areas that are vulnerable to disasters.

With growing population, the world’s exposure to natural hazards is inevitably increasing, as well as the global energy demand. Energy consumption by use of fossil fuels releases CO2 emissions into the atmosphere intensifying the natural greenhouse effect and causing global warming. Buildings are one of the main contributors to world energy consume and CO2 releasing. Therefore an efficient use of energy in buildings is key to reduce CO2 emissions.

In the aftermath of a disaster, the basic needs of the victims are generally solved with first aid and basic plastic tents. While this is a necessary step usually doesn’t involve essential environmental and sustainable premises thus not providing an adequate architectural response. In the relief phase in the event of a disaster, the need for energy efficient and sustainable solutions for emergency shelters appears in order to protect the environment and conserve scarce natural resources.

In this thesis, the current state of the art in emergency shelter design and the emergency management in the world are investigated. A research on the current green standards for buildings is conducted.

Supported on this research, a selection of sustainable criteria for emergency shelters is provided. This criteria is the base for an approach to a new green rating system focused on emergency architecture.

Three prototypical emergency shelters are selected and analyzed from energy efficiency point of view. These case studies are checked through the new green rating system previously established. Following this, the emergency shelters are simulated in five different cities of Turkey corresponding to different climatic zones of the country. Turkey has had a long history of large earthquakes that makes it an appropriate field for the research and improvement of energy efficient and sustainable post-disaster emergency shelters.

ACİL DURUM MİMARLIĞINDA ENERJİ VERİMLİLİĞİ VE SÜRDÜRÜLEBİLİRLİK İÇİN BİR YAKLAŞIM: TÜRKİYE'DEKİ AFET SONRASI BARINAKLARININ DEĞERLENDİRİLMESİ

ÖZET

Doğal ve beşeri afetler her yıl büyük can ve ekonomik kayıplara neden olan sürekli bir tehdit yaratmaktadır. Artan nüfus ile, dünyanın maruz kaldığı doğal afetler kaçınılmaz olarak artmaktadır. Artan nüfus aynı zamanda küresel enerji talebini de arttırmaktadır. Fosil yakıt kullanımından dolayı ortaya çıkan enerjinin tüketimi CO2 gazının serbest kalmasına, atmosferde sera etkisinin yoğunlaşmasına; böylelikle küresel ısınmaya neden olmaktadır. Bu gibi kirlilik oluşturan maddelerin yanı sıra binalar dünyaya en çok zarar veren; gelişmiş ülkelerde kullanılan enerjinin yarısını tüketen ve iklim değişikliğine sebep olan gazların yarısından fazlasını üreten başlıca kirletici unsurdur.

Ancak, enerji kullanımının ve CO2 emisyonlarının azaltılması duyulan ihtiyaca rağmen, genellikle afet sonrası durumlar, temel barınma ihtiyaçlarını karşılamaya yetersiz ve verimsiz yollar ile çözülmektedir. Bu çözümler genel olarak temel çevresel ve sürdürülebilir önerilere uymayan, yeterli mimari yanıtlar değildir.

Bu tez çalışması, enerji verimliliği sağlayan ve çevreye daha az zararlı etkisi olan sürdürülebilir acil durum barınaklarını geliştirmek için etkili faktörler hakkında bir ön analizi temsil eder. İlk olarak, barınakların konumlanacağı afet bölgesindeki iklim faktörünün göz önüne alınmasına ve tasarıma entegre edilmesine işaret edilmiştir. Öte yandan, sürdürülebilirlik kriterlerinin barınakların tasarım, inşaat ve geliştirilmesine dahil edilmelidir. Bu tez, bu tip mimari yapıların enerji verimliliğinin iyileştirilmesi için daha iyi bir değerlendirme yolu sağlayabilecek ileri bir araştırmaya temel olmayı hedefliyor.

Türkiye'nin farklı iklim bölgelerinde yer alan üç acil sığınma evleri hakkında yapılan simülasyon çalışmaları ve analizleri sayesinde farklı tip yapı kabuklarının enerji performansı hakkında veri elde etmek mümkün olmuştur. Prototip acil durum barınakları için yerel anlanlandırma ve adaptasyonu sayesinde daha verimli yapılar elde etmek mümkündür. Bu tezde, acil durum barınakları odaklı yeni bir sürdürülebilirlik derecelendirme sistemi geliştirmiştir. Tezin örnek çalışmasında bu üç farklı barcnak sürdürülebilirliğin farklı alanlarındaki güçlü ve zayıf yönlerini kontrol etmek amacvyla bu derecelendirme sistemi ile değerlendirilmiştir.

Acil durum mimarisine yönelik bu yeni sürdürülebilirlik derecelendirme sistemi, acil durum barınaklarının enerji verimli performansı için gerekli çevre kriterlerini destekleyen yeni bir kılavuz ve yöntem olmayı hedeflemektedir. Sistem aşağıdaki 5 parametreye dayanmaktadır:

– Yer seçimi. Afet sonrasında barınakların yerleşim alanlarının seçimi ve gelişiminde çevre üzerindeki etkiler ve sürdürülebilirlik kavramı dikkate alınmamaktadır. Çevresel açıdan sürdürülebilir arazi seçimi ve gelişim ilkeleri mevcut şartları korumak ve çevresel bozulmaları (erozyon, ormanların yok edilmesi gibi) önlemek için sunulmaktadır. Yerel çevresel kaynaklara verilen önemin yetersizliğini önlemek için araziye ve tarımsal geçim kaynaklarına verilen zararı minimize eden, emniyet ve güvenliği sağlayan maddeler önerilmiştir.

– Malzeme. Afet sonrası inşaat projeleri için çevresel olarak en uygun malzeme kullanımını tanımlamayı amaçlamaktadır. Çevre ve insanlar üzerinde en az olumsuz etkiye sahip barınakların tasarımı için malzeme seçimi, satın alma ve kullanımı hakkında sürdürülebilir farkındalık getiren bir yaklaşım sunmaktadır.
– Enerji verimliliği ve yenilenebilir enerji. Acil durum barınaklarının ihtiyacı olan enerjiyi en sürdürülebilir şekilde karşılamak için yol göstermektedir. Enerji verimliliğini artırmak ve atmosfere verilen CO2 gazını azaltmak için yenilenebilir enerji kaynaklarını ve teknolojilerin kullanımını içermektedir.
– Su verimliliği. Çevresel sürdürülebilirliği vurgulayarak kullanıcının refahını arttıran su ve sanitasyon sistemlerini teşvik etmekte ve uygulamaktadır.
– İç mekan konforu. Sakinlerinin refahı için iç mekan konforuna katkıda bulunmayı hedeflemektedir. Bu da havalandırma, gün ışığı, konfor sıcaklığı ve diğer etkili faktörler ile ilgili doğal ve mekanik sistemleri sürdürülebilir bir noktadan içerir.

Enerji verimliliği ve sürdürülebilirlik alanlarında acil durum mimarlığını anlamak için uygun temsili örnekler arasında bir analiz yapılması gerektiği düşünülmüştür.

Dünya çapında farklı yerlerde uygulanmış üç acil durum barınağı, Türkiye'de uygulandığında göstereceği enerji performansını incelemek için seçilmistir. Türkiye bu çalışma için ideal bir alandır çünkü ülke önemli bir deprem bölgesi üzerindedir (7 büyüklüğü aralığında) ve bölgelerinde sundugu geniş iklim çeşitliligi kısmen afetlere açık diğer bölgelere çıkarım olabilmektedir.

Yerel ölçekte geniş bir analiz sağlamak amacıyla farklı iklimlerde simülasyon çalışmaları yapılmıştır. Her acil durum barınagı gerçek durumlarda kullanılan seçenekleri en geniş kapsayacak şekilde seçilmiştir ve bunların her biri, acil durumlarda kullanılan malzemelerin ana tipolojilerini temsil eder: ahşap, plastik ve metal kabuklu yapı tipolojileri. Seçim için kullanılan diğer kriterler: Seçilen acil durum barınakları önemli sayıda inşa edilmiştir ve deprem sonrası durumlarda kullanılmıştır; tümü 4/5 kişilik bir aile için, 18m2 etrafında inşa alanı (5 kişilik bir aile için kişi başı en az 3.5m2 kapalı yaşam alanı kuralına dayalı), tek katlı ve basit inşaat modeline sahiptir; sakini olacak insanlar için özel inşa edilmiş acil durum barınaklarıdır. Ayrıca yerel koşullara dayanabilen bir çeşit tasarım verimliliği teşvik etmektedir.

– Ahşap kabuklu tipoloji. 2009 yılındaki Sumatra depreminde kullanılan 18m2'lik, kereste iskeletli, palmiye çatılı ve ahşap duvarlar ile yapılan barınaktır. Barınak yerel malzemelerden tedarik edilmiştir ve montaj için özel alet ya da ekipman gerektirmez. Malzemelerde strüktür için ahşap iskelet, kontrplak duvarlar, palmiye fiber tavan ve palmiye hasır vardır. 5 kişilik bir yapım ekibi tarafından hızla 2 gün içinde inşa edebilir.
– Plastik kabuklu tipoloji. 2010 yılındaki Haiti depreminde kullanılan 18m2'lik çelik konstrüksiyon ve plastik kaplama duvar ile yapılan barınaktır. Barınak için kısmen yerel kaynaklı ve kısmen prefabrik malzemeler kullanır. Prefabrike çelik konstrüksiyon çözümü ithal ve nispeten pahalı olsa da, plastik kaplama duvarlar yerel ve ucuz elde edilebilir. Malzemeleri ülkeye geldiği andan itibaren barınak hızla 2 günde inşa edilebilir.
– Metal kabuklu tipoloji. 2011 yılındaki Van depreminde kullanılan güçlendirilmiş alüminyum profil iskelet ve duvarlarla yapılmış ve poliüretan dolgulu metal panelli çatı ile yapılan prefabrik bir barınaktır. Mevlana evi olarak adlandırılan barınak, 18 m2'lik kullanım alanına sahip bir prefabrik yapidır. Her

evde 4/5 kişi konaklayabilir. Herhangi bir temel ya da yapısal montaj gerekli değildir.

Yeni bir sürdürülebilirlik derecelendirme sistemi aracılığıyla yapılan değerlendirmelerde ahşap barınak plastik ve metal barınaklara göre daha iyi bir sürdürülebilir davranış gösterdiği görülmüştür. Bu sonuç, ithal malzeme veya prefabrik sistemler kullanımı yerine yerel malzeme kullanımının önemini pekiştirmektedir. Sürdürülebilirlik derecelendirme sisteminde ayrıca geçerli acil barınaklarda yenilenebilir enerjinin kullanım eksikliğini vurgulamaktadır. Bazı temiz enerji sistemlerinin tasarım ve kuruluşu ile (örneğin güneş enerjisi veya rüzgar enerjisi) enerji tüketimi ve de CO2 emisyonu önemli ölçüde azalabilmektedir. Tasarım yapının yeniden kullanılması üzerine yapılmış ise, yenilenebilir enerji kaynaklarının dahil edilmesi için ilk yatırım göze alinabilir. Bunun yanında, fiyat konusunda bu felaket bölgesinde belirli özelliklerine uyarlanmış bir yerel olarak üretilen barınak, görüş ekonomik ve ekolojik açıdan daha sürdürülebilir olabilir olduğu görülmektedir. Ayrıca, fiyat konusunda felaket bölgesinin belirli özelliklerine uyarlanmış, yerel olarak üretilen barınak ekonomik ve ekolojik açıdan daha sürdürülebilir olabilir.

Yapılan acil durum barınaklarının enerji simülasyonları aracılığıyla metal kabuklu barınak, plastik barınağa göre daha iyi bir enerji davranışı ve daha az enerji tüketimi sergilediği gösterilmiştir; plastik barınak ise en kötü enerji davranışı ve en büyük enerji tüketimine sahiptir. Bu metal barınaklardaki sandviç panellere entegre edilmis izolasyondan ve plastik barınakların izolasyon eksikliğinden kaynaklanmaktadır. Aslında bu gerçek barınaklarda doğal ve sürdürülebilir izolasyon kullanımının önemini pekiştiriyor (Etkilenen felaket alanının yerel özelliklerine malzemede adapte edilen kalınlık ve tip ile birlikte) ve en yaygın olarak kullanılan plastik acil çadırların yetersiz olduğu ve yerine malzemelerin daha geniş bir çeşitlilik aralığına sahip olması gerektiği bu çalışmada kanıtlanmaktadır.

Acil durum barınaklarının hiçbiri tek başına tam olarak yeterli enerji verimli ve sürdürülebilir bir çözüme sahip değildir. Bir varsayımsal felaket durumunda, bu çalışmanın sonuçları ışığında, bir acil durum barınağı çözümü için analiz edilmiş faktörler ve elde edilen sonuçlar dikkate alınarak seçim yapılmalıdır. Kullanılan acil barınma yeni sürdürülebilirlik derecelendirme sistemi yaklaşımında en yüksek puan ile uygulamalıdır. Ayrıca bu uygulamanın fazla sayıda yapılacak üretim için uygun ekonomik maliyete sahip olması gerekmektedir. Ve son olarak, acil durum barınakları için her birinin enerji verimliliğinin güçlü olduğu yönlerini birleştirmek ve geliştirmek gerekir. Bu yönlerin uygulanmasıyla, tasarlanmış ve / veya yeniden kullanılan acil durum barınakları enerji verimliliği ve sürdürülebilirlik açısından doğru yönde olacaktır.

1. INTRODUCTION

A disaster is a hazard resulting in a sudden event of substantial extent causing widespread physical damage or destruction, great loss of life, or drastic change to the environment. A disaster can be man-made like a war or natural such as earthquakes, floods, etc.

Disaster risk management is the concept and practice of reducing disaster risks through systematic efforts to analyze and reduce the causal factors of such disasters. Reducing exposure to hazards, lessening vulnerability of people and property, wise management of land and the environment, and improving preparedness for adverse events are all examples of disaster risk reduction. There are 4 phases in the management of a disaster or emergency situation: Response, Recovery, Mitigation and Preparedness.

- The Response phase of an emergency starts with search and rescue of survivors and the fulfilling of the basic humanitarian needs of the affected population.
- The Recovery phase starts after the immediate threat to human life has subsided.
- The Mitigation phase concerns knowing and avoiding unnecessary disaster risks.
- The Preparedness phase focuses on preparing equipment and planning procedures for use when a disaster occurs.

Usually the response phase in the aftermath of the disaster consists of the provision of tents, blankets and national and international aid (food and medicines). The temporary allocations for the people affected by a disaster are known as emergency shelters or post-disaster housing. Although the measures adopted in the response phase are absolutely necessary they generate deficient shelters due to the adverse weather conditions of some of the affected regions and a lack of a sustainable performance towards the environment through all the process. This deficiencies lead to poor conditions and people discomfort and suffering.

The energy crisis and the climate change have made clear the implications of the dependence on fossil fuels and the need to conserve and reduce the use of energy in the buildings. The building industry is responsible for 25 to 40% of energy consumption, 30 to 40% of greenhouse gas emissions and 30 to 40% of solid waste generation. [1]

But, despite of the need of reducing energy use and CO2 emissions, usually post-disaster situations are solved with inadequate and inefficient response that cannot cover the basic shelter needs. These solutions are not an adequate architectural response as generally they don't meet basic environmental and sustainable premises.

Emergency shelters normally neglect energy efficient measures, in part due to the need of a fast response but also for a lack of guidelines and regulations towards an environmentally sensitive design focused on post-disaster architecture.

This thesis is an approach to a new green rating system specifically directed to provide practical standards and guidelines for emergency shelters in the fields of energy efficiency and sustainability. Case study emergency shelters are simulated to analyze their energy performance in the diversity of climates of Turkey in order to determine their energy efficiency and environmental strengths and weakness.

Turkey is selected as research field due to the amount of earthquakes, the diversity of climatic zones and the lack of an adequate architectural response to this disasters.

An energy efficient strategy is important in the design, implementation and maintenance phases of emergency shelters. Tendency must be to design shelters and settlements which use minimum energy and adopt a systematic environmental aware behavior.

1.1 Literature Review

As stated by OXFAM (2009) by 2015, on average over 375 million people per year are likely to be affected by climate-related disasters.[2]

Given the pivotal role that emergency shelters plays in the aftermath of disaster, it is important to establish the state of the art in emergency architecture, the temporary post-disaster housing constructed after a humanitarian disaster.

The current thesis examines the introduction of energy efficient measures and environmentally friendly design on emergency architecture.

The U.S. Green Building Council (USGBC) and the Building Research Establishment introduced the LEED (2000) and BREEAM (1990), rating systems for the design, construction and operation of high performance green buildings. However, among the building type covered by this rating systems, there is no special mention done to emergency architecture.

This area has been neglected until recently, as the majority of the literature on emergency management has traditionally focused on the effect of disasters in population and economy but not on sustainability or post-disaster architecture. The effort of NGOs such like Red Cross, WWF and United Nations, is crucial in the development of knowledge and techniques to introduce standards and green ratings in emergency architecture. In this sense, the American Red Cross and the World Wildlife Fund has recently developed GRRT (2010), the concept for implementing integrated disaster relief to provide a sustainable solution.

Architecture for humanity (2010) gives also an account of collaborative working that addresses climate change by trying to reduce the footprint of the built environment and mitigating the effects of rapid urbanization in unplanned settlements.

In a recent paper, Arslan (2005) explores the re-design, re-use and recycle of temporary houses as a way to save money, protect the environment and conserve natural resources of the affected region.

One of the few recent examples of technical studies focusing on the subject is provided by UIC (Universitat Internacional de Catalunya) as a Master's Degree of International Cooperation in Sustainable Emergency Architecture.

Turkey is a very vulnerable country to natural disasters due to the high earthquake activity. And according to Erdik and Aydinoglu (2002), Turkey is especially vulnerable due to ineffective control/supervision of design/construction, high rate of urbanization, regulations with limited enforcement and environmental degradation.[3]
This thesis researches typological shelters as provided by IFRC (2011) according to the most common by used envelope materials. This aims to supply a range of options to inform shelter decision-makers in the immediate aftermath of a disaster, with the precise knowledge of their performance and detailed information to enable rapid and sustainable effective procurement.

Although the case studies described in this thesis are located in the climatic zones of Turkey, they are used to help understand the results obtained and consider implications of the findings also at a global scale.

1.2 Aim of Thesis

The aim of the thesis is to present an overview of the issues and steps involved to introduce sustainable and energy efficient criteria in emergency shelters used following a natural disaster. On one hand, this thesis seeks to approach a new assessment method and green rating system specially focused on green emergency architecture. This green rating system, in the form of a checklist, aims to help as a practical guide to create, develop and improve a post-disaster sustainable housing system. On the other hand, there is an aim to analyze prototypical shelter examples through a simulation of their energy performance. Crosschecking both the green checklist and the result of the energy simulation will produce a body of work that aims to optimize the design of emergency shelters in terms of energy efficiency and ecology and be a useful tool to the different agents involved in the post-disaster relief:

- Governments: in a global scale they are responsible of the reaction given to a natural or human disaster. A better understanding of the importance of a sustainable response is offered as well as guidance on how to implement the green criteria in post-disaster housing programmes.
- Organizations: humanitarian organizations provide shelter and emergency aid. An introduction of standardized guidelines and a practical checklist is offered in order to achieve a globally sustainable response with a local understanding of the environment.
- Architects: designers involved in humanitarian labors could have a tool to design quickly deployable, affordable and sustainable emergency shelters. These standards provide technical information on the sustainable approaches to emergency architecture including construction, materials and technologies, energy efficiency and ecological aspects, alternative water supply and sanitation systems, solid waste and environmentally friendly site management.
- Individuals: in the aftermath of a disaster usually the people affected is also involved on the reconstruction or settlement of emergency shelters. A guide for an

environmental behavior is introduced to help reduce the use of energy and contamination to the environment.

2. EMERGENCY ARCHITECTURE

Emergency architecture is a type of architecture integrated in a wider field known as a disaster risk management that deals with all the phases of a disaster. This chapter focuses on the pivotal importance of emergency architecture through the research of the temporary aspect of this architecture, the types of disasters that aims to relief and the environmental element that this field of architecture should incorporate.

Emergency architecture is encompassed under diverse governmental frames, according to the country where the disaster takes place. Key countries leading with disaster risk management and their disaster strategies are analyzed to have a wider vision of the different approaches to these situations.

Moreover, a research of the state of the art in emergency shelters, constructed or as a conceptual design, becomes necessary to understand the current and future possibilities of this kind of architecture regarding the reduction of the use of energy and the environmental contamination.

2.1 Background

Emergency architecture is the application of an architectural approach to emergency management that according to the UNISDR (2009) engages all the "comprehensive and coordinated ways to respond to the entire spectrum of emergency needs".[4]

Emergency architecture helps people affected by disasters by supplying a temporary or semi-temporary architectural solution to alleviate the basic human need of shelter.

2.1.1 Temporary architecture

Emergency architecture is a type of architecture intended to be temporary or semi-temporary. Temporary architecture has been around since humans first began to build, attached to a nomadic life where there was the need to create an easily mountable and dismountable space for living that could protect them from weather and where they could store their food.

It is possible to find many examples in ancient civilizations about the extensive use through history of temporary shelters:

– **Yurt:** The nomads in the steppes of Asia used for centuries a portable shelter consisting of an expanding wooden circular frame carrying a felt with a south-facing orientation. Yurts are still the most common type of habitation in Mongolia because the practicality, comfort, and portability of the yurt allow these people to move every few months together with their herds, as shown in Figure 2.1.

Figure 2.1: A yurt in the plains of Siberia [5]

– **Tipi:** mostly used by the Indians of the central plains of North America, is one of the best portable homes designed from the point of view of habitability, comfort and adaptation to extreme weather conditions. As shown in Figure 2.2 the tipi is a solid and stable construction (even in the wind due to its conical shape) and easily raised.

Figure 2.2: A Sioux Indian Tipi in 1907 [6]

– **Wigwam:** the wigwam or wickiup it’s a Native American dwelling commonly having a domed, round shelter structure, formed with a frame of arched poles, most often wooden, which are covered with some sort of roofing material: bark, hides, or mats, as seen in Figure 2.3.

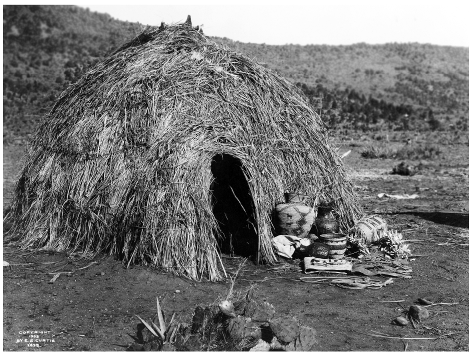

Figure 2.3: A Wigwam in 1903 [7]

– **Lavvu:** is a temporary dwelling used by the Sami people of northern Scandinavia. It has a design similar to a Native American tipi but is less vertical and more stable in high winds. Being more centered to the ground, the Lavvu is better able to endure the fierce winds of the Scandinavian tundra, thus a more stable structure. Its simplicity enables the Sami to move quickly with their semi-domesticated reindeer herds at a moment's notice, as seen in Figure 2.4. Similar constructions as the Lavvu are the chum (used by the nomadic Yamal-Nenets and Khanty reindeer herders of northwestern Siberia of Russia) and the goahti, a Sami hut.

Figure 2.4: A Sami family in front of Lavvu in 1900 [8]

– **Bedouin tent:** the Bedouins, a desert-dwelling Arabian ethnic group with semi-nomadic life, travel and live in tents. These tents have compressive struts and tensile membranes that utilize the same principles as modern tensile engineering systems.[9] In Figure 2.5 a Bedouin tent in the dessert is shown.

Figure 2.5: A Bedouin Tent in Jordan [10]

In an age where the environment is undergoing to fast changes that have a social, cultural and ecological impact, a form of architecture that is flexible, easy to construct and has minimal ecological impact has a great value and importance.

2.1.2 Natural and human disasters

Disasters fall into two major categories: man-made disasters and natural disasters. Natural disasters are brought about by change in natural phenomenons. The extent of loss experienced is dependent on the vulnerability of the population. On the other hand, man-made disasters are influenced by humans and they are often as a result of negligence and human error among other factors.

– Natural disasters: Include events such as earthquakes, floods, volcanic eruptions, tornadoes, landslides and hurricanes, among others.

– Man-made disasters: These include technological hazards, sociological and transportation hazards, wars, radiation contamination, oil spills or global warming. Global warming has a wide impact from rising sea levels, desertification to ocean acidification.[11]

In both instances, casualties should be treated immediately and the best way to meet this end is providing the necessary relief measures. The costs associated with handling of the manmade and natural disasters run to billions every year and this negatively affects the economy as shown in Figure 2.6.

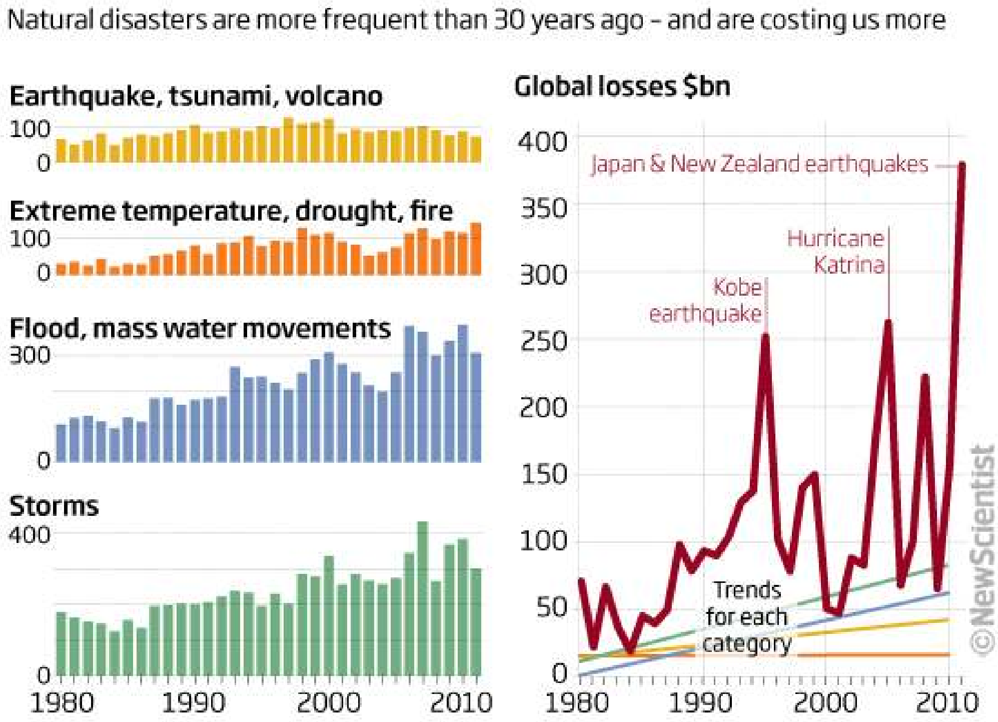

Figure 2.6: Economic impact of natural disasters from 1980 to 2010 [12]

2.1.3 Environmental protection

A concern for environmental conservation and the preservation, restoration and/or improvement of the natural environment, have surfaced throughout human history but it wasn't until the 1960's, that activity of environmental movements created awareness of the various environmental issues. Especially in the 70's the environmental movement gained rapid speed in the U.S. and around the world due to the first oil crisis.

In 1971 the international organization Greenpeace is founded. Greenpeace proves adept at using the media to raise awareness about industrial pollution, endangered species protection, and other environmentalist concerns.

The UN's first major conference on international environmental issues, the United Nations Conference on the Human Environment (also known as the Stockholm

Conference), was held on June 5–16, 1972. It marked a turning point in the development of international environmental politics.

Programs that follow and track disasters have improved throughout the years. In the 1970s, only the specialized departments of large companies, universities, and the government covered disasters. Desktop systems and computer communications emerged as a technology for linking emergency professionals on a global basis in the eighties.

In the 80s after the discovering of holes in the ozone layer over the Antarctic, starts awareness of the chlorofluorocarbons (CFCs) that destroy the ozone layer.

With the 1990s, computer equipment became more powerful and is now an essential component of disaster operations worldwide. Today Earth observation satellites provide basic support in pre-disaster preparedness programs: in-disaster response, monitoring activities, and post-disaster reconstruction.

Rising frequency, amplitude and number of natural disasters and attendant problem coupled with loss of human lives prompted the General Assembly of the United Nations to proclaim 1990s as the International Decade for Natural Disaster Reduction (IDNDR) and in 1997 the Kyoto protocol was adopted, an international agreement that sets binding obligations on industrialized countries to reduce emissions of greenhouse gases.

2.2 Disaster Risk Management in the World

According to the United Nations definition, disaster risk management aims to "avoid, lessen or transfer the adverse effects of hazards through activities and measures for prevention, mitigation and preparedness".[13]

More frequently, towns and urban agglomerations are affected by natural disasters. Therefore, governmental involvement in prevention, response and mitigation efforts has become increasingly significant.

Every country has, to a greater or lesser extent, relief agencies, humanitarian organizations, policies, approaches and strategies to reduce socio-economic vulnerabilities and other hazards caused by disasters.

Creating disaster resisting societies can only be achieved by strong institutional bodies, knowledge sharing, enhancing awareness and supporting research.

Three disaster risk management government models are presented corresponding to three countries vastly affected by disasters and their strategies to cope with them.

2.2.1 Japan

The Japanese archipelago is located in an area where several continental and oceanic plates meet. This is the cause of frequent earthquakes and the presence of many volcanoes and hot springs across Japan. If earthquakes occur below or close to the ocean, they may trigger tidal waves (tsunami). Japan can have up to 5000 earthquakes each year.[14] Many parts of the country have experienced devastating earthquakes and tidal waves in the past. Among others, the Great Kanto Earthquake, the worst in Japanese history, hit the Kanto plain around Tokyo in 1923 and resulted in the deaths of over 100,000 people. In January 1995 a strong earthquake hit the city of Kobe and surroundings. Known as the Southern Hyogo Earthquake or Great Hanshin Earthquake, it killed 6,000 and injured 415,000 people. 100,000 homes were completely destroyed and 185,000 were severely damaged. A timeline of victims of natural disasters in Japan can be seen in Figure 2.7

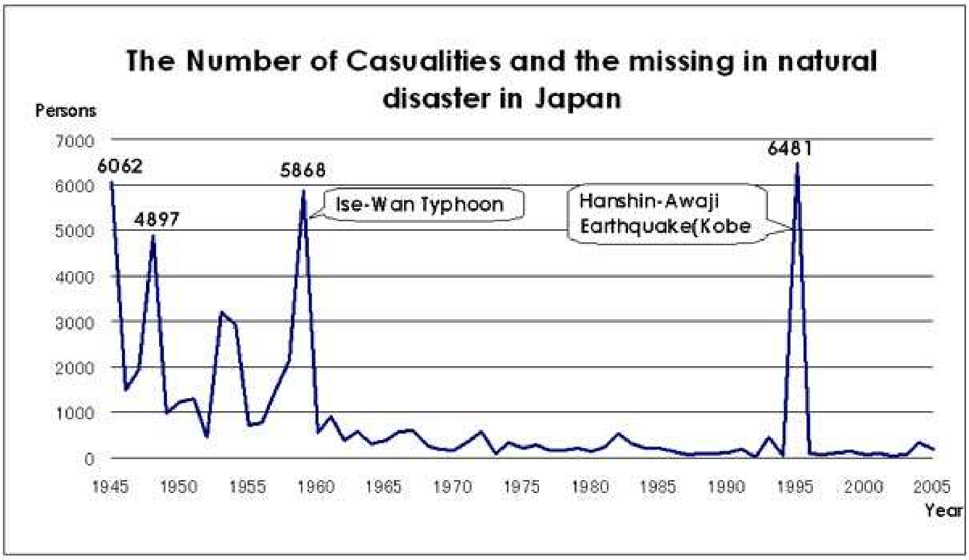

Figure 2.7: Number of the victims of natural disasters in Japan [15]

Japan is the world leader in earthquake disaster management.[16] National Government, local governments and wide range of relevant partners designated public corporations work out disaster management plans and carry them out based on the Disaster Countermeasures Basic Act. Every prefecture (a japanese administrative jurisdiction) has a specific ordinance. For example Tokyo prefecture has Ordinance of Earthquake Disaster Countermeasure of Tokyo Metropolitan and the Aichi Pref., Japan Shelter management manual of Aichi Prefecture, Japan

Japan's effective response is a clear reflection of the focused preparations the country has made in disaster preparedness, with even more determination since the Kobe earthquake in 1995.

Japan has invested heavily in disaster risk reduction, strengthening the seismic performance of buildings and national and local response capacities and warning systems. In this regard, Japan can serve as an example for others countries in disaster-prone areas of Asia and around the world.

It is clear that disaster risk reduction efforts in policymaking, risk-sensitive land-use planning, construction and community preparedness pay dividends by saving lives and reducing losses. While the damage to property can be extensive, much of the economic cost of this damage and loss will be covered by insurance and other types of disaster risk financing.

Japan has also clearly shown the value of early warning systems and evacuation plans and drills for reducing loss of life and injury. After the Fukushima nuclear disaster on 11 March 2011 the government has opened shelters across many parts of northeastern Japan, initially sheltering more than 500.000 people. An estimated 200.000 people were also been evacuated or re-evacuated from the areas around the Fukushima Daiichi and Daini nuclear plants.

2.2.2 USA

The United States experiences a variety of natural disasters throughout the year. Because of hurricanes on the Pacific, Atlantic, and Gulf of Mexico coasts, earthquakes near the San Andreas and other fault lines, volcanic eruptions, tornadoes in the plains, and floods throughout the Midwest, the United States suffers approximately $1 billion in losses each week.

Figure 2.8 shows the increasing number of natural disasters in the United States.

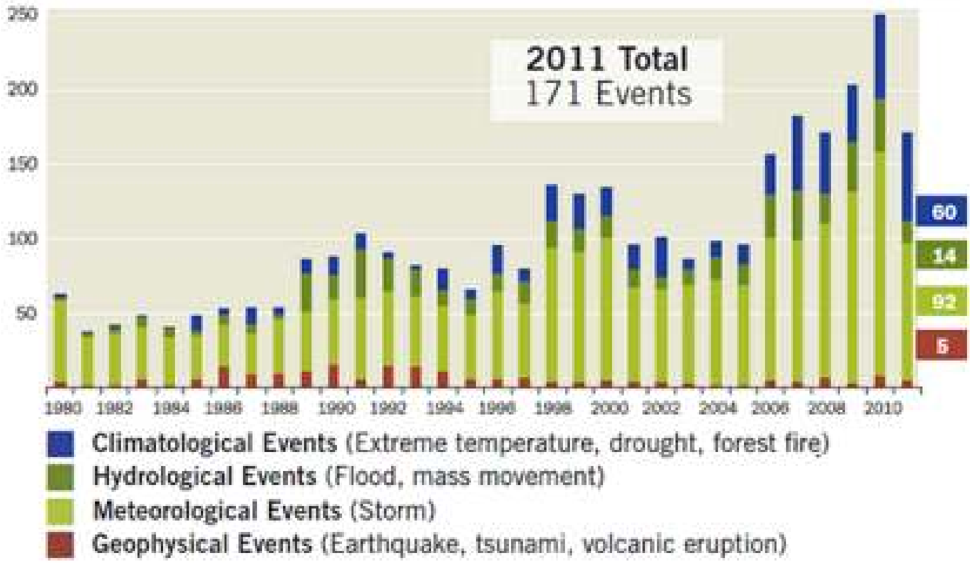

Figure 2.8: Natural disasters in the United States 1980-2011, number of events and annual totals [17]

As an integral part of their disaster risk management measures, the United States has the Federal Emergency Management Agency (FEMA), part of the U.S. Department of Homeland Security (DHS), created in 1979 to reorganize many duplicative agencies and programs existing. FEMA works across the country to support citizens in the many forms of disasters - a hurricane, an earthquake, a tornado, a flood, a fire or a hazardous spill, an act of nature or an act of terrorism.[18] It has a Design and construction guidance for community shelters and a National Response Framework. The two main components of the strategy are to increase public awareness of natural hazard risk and to reduce significantly the risk of the loss of life, injury, economic cost, and destruction of natural and cultural resources due to natural disasters. Five key elements are included, in order to make the strategy a successful one: hazard identification and risk assessment; applied research and technology transfer; public awareness training and education; incentives and resources; and leadership and coordination.

Also, the first organized aid for disaster victims began in the Unites States with the American Red Cross (ARC) when the founder, Clara Barton, organized the distribution of food and relief supplies after an 1881 disaster. Since then, the ARC has continued to be the primary agent of emergency disaster relief.[19]

2.2.3 China

China is one of the countries most affected by natural disasters. It had 5 of the world's top 10 deadliest natural disasters; the top 3 occurred in China: the 1931 China floods, death toll 1 million to 2.5 million, the 1887 Yellow River flood, death toll 0.9 million to 2 million, and the 1556 Shaanxi earthquake, death toll 0.83 million, as seen in Figure 2.9

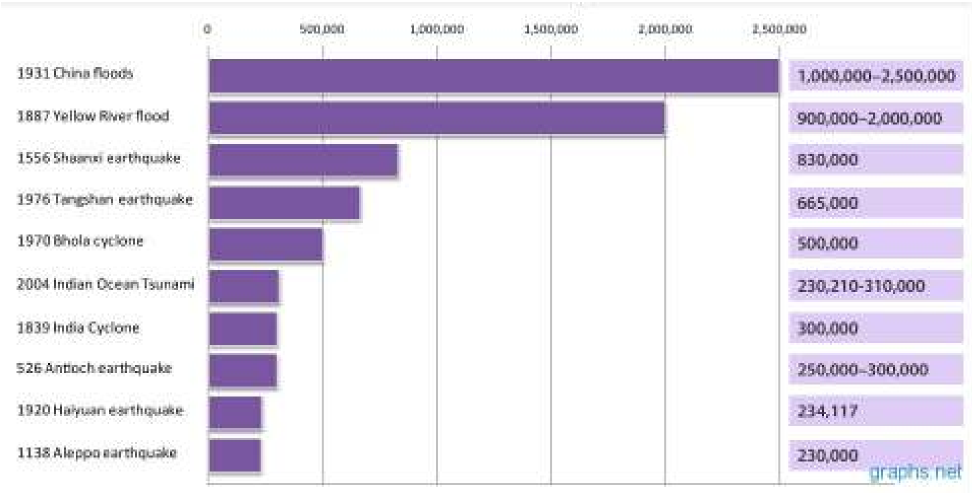

Figure 2.9: List of 10 natural disasters by death toll [20]

Natural disasters occur frequently in China, affecting more than 200 million people every year. In the course of recorded history, many types of natural disasters - except volcano eruptions - have occurred in China, which include floods, droughts, meteorological, seismic, geological, maritime and ecological disasters as well as forestry and grassland fires.

China has adopted a natural disaster risk management regime featuring central leadership, departmental responsibility, and graded disaster administration with major responsibilities on local authorities. Under the unified leadership of the State Council, central government agencies that are responsible for coordination and organization of disaster reduction and relief. Local governments have set up corresponding units with similar functions in coordinating disaster reduction and relief.

The National Disaster Reduction Center (NDRC) of the Ministry of Civil Affairs (MCA) is a specialized agency under the Chinese Government engaged in information services and supporting decisions on various natural disasters. It provides reference for disaster-management departments in their decision-making and technical support for China's disaster-reduction undertakings by way of collecting and analyzing disaster information, assessing disasters and emergency relief, and analyzing and studying disasters using such advanced technology as satellite remote sensing.

2.3 Disaster Risk Management in Turkey

Turkey is located in one of the most seismically active regions of the world (surrounded by three major plates: African, Eurasian and Arabian, and two minor plates, Aegean and Anatolian). This country is the fifth country in the world regarding the damage produced by Earthquakes (after China, Iran, Russia and Peru). Approximately 96% of the country is under the risk of earthquake hazard in various scales and 98% of the population lives in these areas.[21]

In the following Figure 2.10 are shown the areas more prone to have earthquakes in Turkey, sorted by their PGA (Peak ground acceleration).

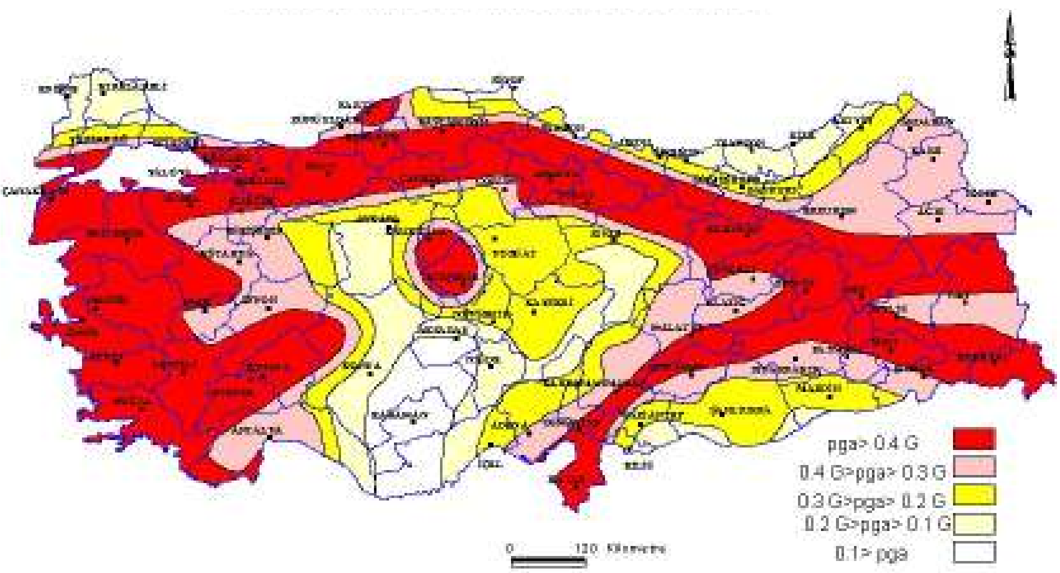

Figure 2.10: Earthquake hazard map of Turkey [22]

During the 1990s, Turkey experienced a series of severe disasters, including the Erzincan Earthquake in 1992, floods in the Black Sea Region in 1998, and the

Adana-Ceyhan Earthquake in 1998. On August 17th, 1999, an earthquake of 7.4 on the Richter scale hit the Marmara region. Over 15.000 lives were lost and approximately 400.000 to 600.000 people were left homeless. The quake had extensive damage to Turkey's industrial heartland, with a wealth loss up to 6.5 billion USD (3.3% of GNP). The Marmara Earthquake was the most damaging earthquake to hit Turkey during the 1990s. A detailed list of earthquakes according to the people affected is given in Figure 2.11.

Disaster	Date	No Killed
Earthquake (seismic activity)	26-Dec-1939	32,962
Earthquake (seismic activity)	17-Aug-1999	17,127
Earthquake (seismic activity)	29-Apr-1903	6,000
Earthquake (seismic activity)	26-Nov-1942	4,000
Earthquake (seismic activity)	1-Feb-1944	3,959
Earthquake (seismic activity)	24-Nov-1976	3,840
Earthquake (seismic activity)	20-Dec-1942	3,000
Earthquake (seismic activity)	26-Nov-1943	2,824
Earthquake (seismic activity)	19-Aug-1966	2,394
Earthquake (seismic activity)	6-Sep-1975	2,385

Figure 2.11: Top 10 natural disasters in Turkey for the period 1900 to 2012 sorted by number of killed [23]

As a consequence of the devastation created by the earthquake the government of Turkey shifted its previous policy, mainly focused on post-disaster actions, towards a more active pre-disaster and risk reduction approach.

In 2009 the AFAD, Prime Ministry Disaster and Emergency Management Presidency of Turkey, (in Turkish: T.C Basbakanlik Afet ve Acil Durum Yönetimi Başkanlığı) was created to take necessary measures for an effective emergency management and civil protection. In a Disaster and Emergency situation the AFAD is the only responsible organization.[24]

This organization is the unification of 3 different core institutions (the Directorate of Civil Defense, the Directorate of Disaster Affairs and the Directorate of Emergency

Management) and brought a series of organizational changes such the setting up of regional centers for relief and emergency operations and an Independent National Earthquake Council. This organization is the national platform that, amongst the Governmental, NGO, universities, local authorities and private institutions, provides coordination, and produces and implements policies for reducing risk in Turkey.

One particular transformation that came out of Turkey's policy shift was its risk financing program. The National Catastrophic Insurance Program (NCIP) was set up to provide compulsory insurance for residential buildings in order to transfer risks from individuals and state budget.[25]

There's a 65% probability that Istanbul will be hit by a 7.6 earthquake by 2030.[26] In order to prepare Istanbul for a probable earthquake the Republic of Turkey and the International Bank for Reconstruction and Development signed the Istanbul Seismic Risk Mitigation and Emergency Preparedness (ISMEP) Loan Agreement with an amount of €310 Million on October 18, 2005.[27]The ISMEP focuses on enhancing emergency preparedness capacity, seismic risk mitigation for priority public buildings, and the enforcement of building codes at the city level.

Under the umbrella of AFAD there are several organizations. On the universities side there is the CENDIM, established in 2001 as an interdisciplinary research center for disaster management. Numerous other institutions or governmental bodies where advanced technology products are utilized to help interpret this as possible precursory information related to the seismic threat for Istanbul. Among them there are universities (Middle East Technical University, Istanbul Technical University, Ege University and Bogaziçi University), metropolitan municipalities (Izmir, Istanbul, Ankara, Adana, Izmit, Bursa, Adapazari, Bolu, and Eskisehir), the Atomic Energy Council of Turkey, the Ministries of Environment and Forestry, and a number of private digital geo-data processing companies.[28]

The Turkish Red Crescent Society (TRCS) also plays a major role in rescue and relief operations in Turkey. Turkish Red Crescent (in Turkish: Türk Kızılayı) is the largest humanitarian non-governmental organization in Turkey. They provide relief and alleviate human suffering wherever it may be found, to protect life and health, and to ensure respect for the human being. The Red Crescent is a legal entity and subject to the stipulations of private law; a non-profit and volunteer social service organization, of which relief and services are free and which works for the benefit of the public.[29]

2.4 Outstanding Examples of Emergency Architecture

To develop a sustainable emergency shelter design strategy requires an accurate research of the state of the art on this field to understand what resources are needed, what resources are available and what the present and future possibilities of designs are.

Outstanding examples of emergency shelters have been researched in two fields:

- prototypes of emergency shelters that hasn't been constructed but address sustainability issues in their concept design.
- constructed emergency shelters that have been constructed, proven to be effective in real disaster situations and incorporate sustainable concepts on their construction.

2.4.1 Prototypes of emergency shelters

Four prototypes of emergency shelters that address sustainability issues in their concept design are presented:

– **The Haven.** The Haven is a concept of sustainable emergency shelter that includes solar panels for renewable electricity and can easily be airlifted to disaster areas or war zones. Designed by Song Kee Hong, Timothy Hoo, Ng Teck Tiong and Felix Lee, the Haven units can be flattened and stacked to ease transportation. The panels of these shelters are made using plastic sheets that enclose a thin core of honeycomb and air for insulation and structural strength.

Occupying less space than conventional tents, the Haven units can be stacked against each other to improve protection from the elements. The flip-open platform can accommodate a second occupant and can provide storage space for personal belongings. The units feature roof-mounted solar panels that generate renewable electricity to facilitate charging of portable communication gadgets, as seen in Figure 2.12.

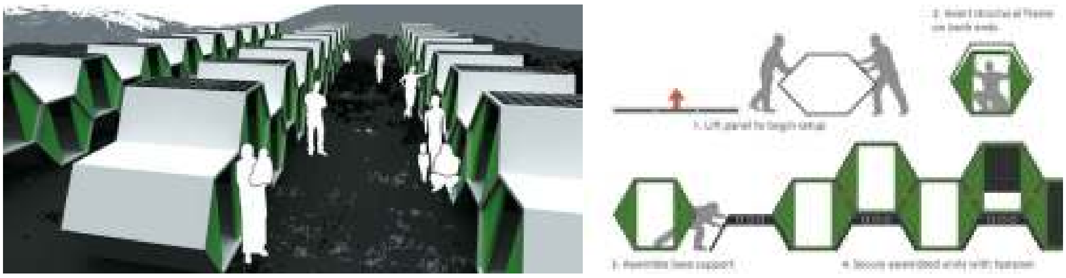

Figure 2.12: The Haven, a concept emergency shelter [30]

– **Uber shelter.** Uber Shelter is concept for a portable housing unit that could help people in meeting their immediate shelter requirements created by disastrous events.[31] This concept is designed by Rafael Smith. This shelter can be very quickly transported and reassembled with just few necessary tools and offer victims with individual living space. Uber shelter is designed to be recyclable and reusable materials. Around two to three personal rooms can be created in this shelter. The assembly system is seen in Figure 2.13.

Figure 2.13: Assembly system of the Uber shelter [31]

– **X2shelter.** Geotectura Architectural Studio has come with a concept emergency shelter that is both green and easy to deploy.[32] The emergency shelter could be airdropped to unreachable disaster zones and is powered by renewable energy. The X2S could be used as a standalone tent for dwelling, sanitation and health care and could also be connected with other X2S shelters to provide shelter for many people.

The emergency shelter optimizes passive ventilation and illumination and also features solar panels and small wind turbines that provide the energy it needs for lighting and telecommunication. The X2S has a rain collector on its roof that stores water inside the structure's poles, as seen in Figure 2.14. After use, the X2S can be folded for reuse or recycling.

Figure 2.14: Deploy system of the X2shelter [32]

– **Exo.** Is a rapid response, short-term post-disaster housing solution. The core system components flat pack to provide extremely efficient storage and transportation. The system can be deployed within hours of an event without the need for tools or heavy machinery. The Exos provide living/sleeping quarters but are augmented with other system components such as portable power generators, climate control equipment, sanitation facilities, walkways, and canopies for common areas.[33] The Exo's design allows for numerous configurations to meet any need or deployment condition. There's virtually no assembly required with the Exo.

An Exo shelter unit is transported in two pieces – a base (floor) and an upper shell (walls and roof) that simply latch together at a deployment site. In Figure 2.15 the transportation system is shown. A small team of 4 people can easily move and assemble a single Exo shelter unit in well under two minutes with no tools or machinery needed.

Figure 2.15: Transportation system of the Exo shelter [33]

2.4.2 Constructed emergency shelters

Four emergency shelters that have been constructed, proven to be effective in real disaster situations and incorporate sustainable concepts on their construction are presented.

– **Paper log houses.** In 1995, the Japanese architect Shigeru Ban designed the Paper Log House in response to the earthquake that devastated Kobe. Four years later, he transformed the Paper Log House to meet the needs of the people of Turkey during the aftermath of the Marmara earthquake. In 2001 Ban used the Paper Log House in India after that country suffered its worst earthquake on record.

Based on the shelter in Kobe, some improvements were applied to fit in with the environment in Turkey. One unit, for example, was 3 x 6m, a different and slightly larger configuration, which was due to the standard size of plywood in Turkey and also to the country’s larger average family size. Secondly, there was more insulation. Shredded wastepaper was inserted inside the tubes along the walls and fiberglass in the ceiling, and also cardboard and plastic sheets were used for more insulation, depending the resident’s needs.

The foundation consists of donated beer crates loaded with sandbags. The walls are made from 106mm diameter, 4mm thick paper tubes, with tenting material for the roof. The 1.8m space between houses was used as a common area. For insulation, a waterproof sponge tape backed with adhesive is sandwiched between the paper tubes of the walls. The cost of materials for one unit is below $2000. The units are easy to dismantle, and the materials easily disposed or recycled.

In Figure 2.16 a model in real scale and a real paper log house in Turkey are seen.

Figure 2.16: Paper log houses used in Turkey [34]

– **Concrete canvas shelter.** Concrete Canvas Shelters are rapidly deployable hardened emergency shelters that require only water and air for construction.[35]

A CCS variant can be deployed by 2 people without any training in under an hour and is ready to use in only 24 hours. Essentially, CCS are inflatable concrete buildings. The compressive structure of CCS has been modeled to be covered with sand or earth (berming) to provide protection and insulation. An electric fan is activated which inflates the plastic inner to lift the structure until it is self supporting. The shelter is then pegged down with ground anchors around the base. The CCS is then hydrated by spraying with water. Water does not need to be potable but must not be sewage and sea water may be used.

The Concrete Canvas cures in the shape of the inflated inner and 24 hours later the structure is ready to use. Access holes can be cut to allow the installation of services. This shelter require nothing more than water and air to construct and can be built by crews with absolutely no training. Within hours of a crisis, the shelters can be set up and ready to live in. It has a lifespan of approximately 10 years.

Figure 2.17 shows the CCS under different weather situations.

Figure 2.17: Concrete Canvas Shelter on site [35]

– **Sandbag shelter.** After extensive research into vernacular earth building methods in Iran, followed by detailed prototyping, Nader Khalili developed the sandbag or 'superadobe' system. The basic construction technique involves filling sandbags with earth and laying them in courses in a circular plan. The circular courses are corbelled near the top to form a dome. Barbed wire is laid between courses to prevent the sandbags from shifting and to provide earthquake resistance. Hence the materials of war - sandbags and barbed wire - are used for peaceful ends, integrating traditional earth architecture with contemporary global safety requirements.

The system employs the timeless forms of arches, domes and vaults to create single and double-curvature shell structures that are both strong and aesthetically pleasing. While these load-bearing or compression forms refer to the ancient mudbrick architecture of the Middle East, the use of barbed wire as a tensile element alludes to the portable tensile structures of nomadic cultures. The result is an extremely safe structure, as see in Figure 2.18. The addition of barbed wire to the compression structures creates earthquake resistance; the aerodynamic form resists hurricanes; the use of sandbags aids flood resistance; and the earth itself provides insulation and fireproofing.

Figure 2.18: Views of the sandbag shelter [36]

– **Pallet house.** The Pallet House by I-Beam Design (New York) was conceived as a transitional shelter for returning refugees. A combined structure for a refugee house would have included a shipping container for all the essential service utility functions, surrounded by the pallet structure. I-Beam's Palette House is made of wooden shipping palettes. Palettes are versatile, recyclable, sustainable, and easily assembled. Their transportation cost is negligible because they are used to carry shipments of clothing, food, and medical supplies to disaster areas.

The Pallet House Design features a creative array of built-in furniture (made of shipping pallets) like a dining area and benches. Houses made from pallets would not only provide temporary shelter but could be adapted using locally available materials into permanent housing.

The design process and the final stage of the Pallet house are shown in Figure 2.19.

Figure 2.19: Model and prototype of pallet shelter [37]

3. AN APPROACH TO A NEW GREEN RATING SYSTEM FOR ENERGY EFFICIENCY AND SUSTAINABILITY IN EMERGENCY ARCHITECTURE

In this chapter, a research of the state of art in green rating systems is conducted to understand the current position of codes and standards towards the architecture used after a natural or human disaster.

Following the research of the state of the art of the main green rating systems, and based on them, an approach to a new green rating system focused on emergency shelters is proposed. This approach to a new green rating system, in the form of a checklist, is supported in several green criteria subdivided as well in subcriteria, explained in detail in this chapter, to be used as a practical tool for the design and implementation of energy efficient and environmental strategies for emergency architecture.

3.1 Green Building Rating Systems

As a result of the increased energy demand in the world, the decrease of natural resources available and the threat of global warming, there has been an increased interest in more sustainable and energy efficient green buildings. A number of organizations have developed standards, codes and green rating systems around the world. The common objective is to reduce the overall impact of the built environment on human health and the natural environment by:

- Efficient use of energy, water, and other natural resources.
- Reduction of waste, pollution and environmental degradation.
- Improvement of occupant health.

Although there is a large number of codes and standards that apply at national or regional level, the three cases selected respond to their wide presence and relevance around the world, in the case of LEED and BREEAM, and in a relevant focus on sustainable post-disaster humanitarian aid projects, in the case of GRRT.

3.1.1 LEED

LEED (Leadership in Energy and Environmental Design) is an ecology-oriented building certification program developed by the U.S. Green Building Council (USGBC). Aims to provide a holistic approach for identifying and implementing practical and measurable green shelter design, construction, operations and maintenance solutions.

Is a performance credit system based on 110 possible points. The main 100 points are distributed across five major credit categories:

– Sustainable Sites (21 points). Encourages strategies that minimize the impact on ecosystems and water resources to preserve habitats and biodiversity.

– Water Efficiency (11 points). Promotes smarter use of water to reduce potable water consumption and targets efficiency measures.

– Energy and Atmosphere (37 points). Promotes better building energy performance through innovative strategies and gives additional points for using alternative sources of energy and investing in green energy infrastructure

– Materials and Resources (14 points). Focuses on material life cycle approach through resource reuse, assessment and optimization, human and ecological health and waste management.

– Indoor Environmental Quality (17 points). Focuses on reaching a better indoor air quality and access to daylight and views.

Plus an additional 10 points:

– Innovation in Design (6 points). Addresses sustainable design measures not covered under the five LEED credit categories.

– Regional Priority (4 points). Addresses regional environmental priorities for

As shown in Figure 3.1, buildings can qualify for four levels of certification:[38]

– Certified: 40–49 points

– Silver: 50–59 points

– Gold: 60–79 points

– Platinum: 80 points and above

LEED is currently the dominant system in the United States market, is adapted to multiple markets worldwide and its considered being the best known, fairly comprehensive and widely accepted green rating system for buildings at present.

Figure 3.1: Four certification levels of LEED [36]

3.1.2 BREEAM

BREEAM (BRE Environmental Assessment Method) is an environmental standard that rates the sustainability of shelters in the UK. The BREEAM environmental assessment aims to minimize environmental impact by ensuring sustainability best practices and energy efficiency.

– Management. Overall management policy, commissioning site management and contractors and procedures issues.

– Energy use. Operational energy and CO2 issues. Energy efficient heating and cooling and controlled metering.

– Health and Well being. Indoor and external issues affecting user health and well being like thermal conditions, daylighting, glare, etc.

– Pollution. Reduction and/or elimination of air, water and light pollution.

– Transport. Transport related CO2 and location related factors like cyclist facilities, public transport links, etc

– Land Use and Ecology. Use of Brownfield sites rather than Greenfield sites, rehabilitation of contaminated land and conservation and enhancement of the site ecology.

– Materials. Consideration of the environmental implications of building materials, including life cycle impacts, responsible sourcing and lifecycle impacts.

– Water. Consumption and water efficiency use. Eg. Installation of low water content WCs, installation of water system with leak detection, grey water recycling, etc.

Buildings are assessed against the above criteria and credits are awarded according to performance.

The individual credits are added up and then weighted to give a final BREEAM rating. The shelter is rated Excellent, Very Good, Good or Pass depending on the total score gained as shown in Figure 3.2.[39]

Assessment score	Assessment rating	Star rating
< 10	Unclassified	–
10 – 25	Acceptable	★
25 – 40	Pass	★★
40 – 55	Good	★★★
55 – 70	Very good	★★★★
70 – 85	Excellent	★★★★★
> 85	Oustanding	★★★★★★

Figure 3.2: BREEAM classification [39]

Although currently a voluntary program, BREEAM is expected to become a requirement for many organizations.

3.1.3 GRRT

The Green Recovery and Reconstruction Toolkit (GRRT) is a training program designed to increase awareness and knowledge of environmentally sustainable disaster response approaches.[40] After the 2004 Indian Ocean tsunami the American Red Cross(ARC) and the World Wildlife Fund (WWF) formed a partnership to help ensure that the recovery efforts of the ARC did not have unintended negative effects on the environment.

Although it is not a building energy performance certification as LEED and BREEAM, this program makes sure that the post-disaster recovery programs includes environmentally sustainable considerations. It aims to provide an integrated solution that not only helps communities recover from disasters, but help them adapt to future environmental threats caused by globalization, climate change, or other factors.

The GRRT was originally pilot tested in Indonesia and Sri Lanka, and has since be used in Chile, Haiti, India, and Pakistan.

The GRRT is made of ten modules, which are designed to be delivered in a one-day training workshop, are briefly described below:

– Module 1. Opportunities after Disasters: Introduction to Green Recovery and Reconstruction. Brief introduction to the concept of green recovery and reconstruction and why addressing environmental concerns in a humanitarian response is critical to a successful recovery process.

– Module 2. Project Design, Monitoring and Evaluation. Guidance on how project design, monitoring, and evaluation of the enviromental impact of a post-disaster humanitarian aid project.

– Module 3. Environmental Impact Assessment Tools and Techniques. Focuses on assessment tools to determine the environmental impact of humanitarian projects regardless of project type or sector.

– Module 4. Green Guide to Strategic Site Selection and Development. Principles of strategic, environmentally sustainable site selection and development for post-disaster humanitarian aid projects.

– Module 5. Green Guide to Materials and the Supply Chain. Focuses on how to use local sources of materials in a sustainable way, and the use of disaster debris and recycled items as shelter material.

– Module 6. Green Guide to Construction. Focuses on key concepts of sustainable design including climate, energy efficiency, and the life cycle of materials.

– Module 7. Green Guide to Water and Sanitation. This module adresses watershed management and techniques to make water and sanitation interventions more environmentally sustainable.

– Module 8. Green Guide to Livelihoods. Assessment and mitigation of the environmental impacts of post-disaster livelihoods recovery projects.

– Module 9. Green Guide to Disaster Risk Reduction. Identification of environmental aspects contributing to risk and the sustainable use of natural resources to help reduce disaster risk.

– Module 10. Greening Organizational Operations. Approach to improve environmental performance of an organization's operational such as office administration, logistics, and vehicle management.

3.2 An Approach to a New Green Rating System for Emergency Shelters

The aforementioned green rating systems doesn't have a section about emergency architecture but have common fields of interest that can be applied to post-disaster housing. Within the scope of this study, and based on them, these main fields are analyzed and reinterpreted to be able to be used as the main criteria selected for the approach and development of a green rating system focused on shelters constructed in the aftermath of a disaster.

3.2.1 Main criteria selection

This approach to a new green rating system oriented on emergency architecture aims to be an assessment method and a guideline to support the environmental criteria necessary for an energy efficient performance of the emergency shelters. It is based in the following 5 parameters:

– **Site selection.** The selection and development of shelter settlement sites following disasters often does not consider the impacts on the environment, and does not take into account the concept of sustainability. Principles of environmentally sustainable land selection and development are offered in order to preserve the existing conditions and avoid environmental degradation (e.g., erosion, deforestation). Tools to avoid insufficient consideration of local environmental resources are given in order to elude further damage to land, agricultural livelihoods, and provide safety and security.

- **Materials.** Aims to identify the most environmentally appropriate materials for post-disaster construction projects. It also provides a sustainable aware approach in the selection, procurement and use of materials for the design of shelters have the least negative impact on humans and the environment.
- **Energy efficiency and renewable energies.** Addresses the most sustainable way to provision energy for the emergency shelters. This includes renewable energy sources and technologies to improve energy efficiency and reduce the releasing of CO2 into the atmosphere.
- **Water efficiency.** Promotes and implements water and sanitation systems that improve user's well-being by stressing environmental sustainability.
- **Indoor comfort.** Aims to achieve a minimum indoor quality environment to contribute to the well-being of the occupants. This includes mechanical and natural systems regarding ventilation, daylight, temperature comfort and other influential factors from a sustainable point of view.

3.2.2 Green rating system for emergency shelters

The aforementioned five main criteria are a base to develope an approach for a new green rating system focused on emergency architecture.

The approach for this new green rating system is a development of these five criteria into further sub-criteria that deepens into the definition of each category and are explained in detail in section 3.2.3

This green rating system aims to provide a systematical assessment and practical method to determine the level of sustainability of an emergency shelter.

At the same time is a tool that allows an objective comparison between emergency shelters.

The performance of each emergency shelter will be categorized using a GREEN, AMBER, or RED scheme. This classification it will be the addition of points for every title.

- GREEN: 20-30 points. Superior performance. Emergency shelter meets most of the criteria and performs adequately for energy efficiency and sustainability criteria.

– AMBER: 10-20 points. Adequate performance. Emergency shelter meets some of the energy efficiency and sustainability criteria but is expected to improve in other areas.

– RED: 0-10 points. Deficient performance. Emergency shelter is expected to improve in most of the areas for energy efficiency and sustainability criteria.

In Table 3.1 below it is shown the rating classification for emergency shelters according to the positive points obtained.

Table 3.1: Approach for green rating system for emergency shelters classification

Score	Rating	Code
20-30	Superior	GREEN
10-20	Adequate	AMBER
0-10	Deficient	RED

Within the scope of this study, the evaluation using the approach of a green rating system focuses on the sections 2 and 3, the sections of Materials and Energy efficiency and renewable. The section of site selection is not included as the emergency shelters selected are abstracted to be in the five climate regions of Turkey in a simulated site. The sections of water efficiency and indoor environment are not included for the lack of verifiable information.

According to this focus on the Materials and Energy efficiency and renewable section, for the specific evaluation of the 3 case studies, the following Table 3.2 shows the rating classification for emergency shelters according to the positive points obtained.

Table 3.2: Green rating classification according to materials and energy efficiency and sustainability

Score	Rating	Code
10-15	Superior	GREEN
5-10	Adequate	AMBER
0-5	Deficient	RED

Table 3.3 below shows the five criteria and their development in sub-criteria for each point.

The table is divided by colours according to the section and sub-points of each one.

The first section, in green, develops the Site selection. The main objective is to limit the environmental impact of the shelter or shelter settlement on local ecosystems, preserving and improving the health and welfare of the surrounding communities.

The second section, in red, develops the Materials. The main objectives are to make an appropriate selection and management of materials with minimal environmental impact.

The third section, in navy blue, develops Energy efficiency and renewable energies. The main objectives are to reduce the amount of energy required by the shelter and find sustainable alternatives for power generation.

The fourth section, in grey, develops Water efficiency. The main objective is to limit or reduce the use of potable water and wastewater generation.

The fifth section, in turquoise, develops Indoor Comfort. green develops the Site selection. The main objectives are to provide comfort and well-being of occupants of the shelter and to guarantee a suitable comfort conditions for the use of the housing.

Table 3.3: Green rating system for emergency architecture. Criteria and subcriteria.

1	**SITE SELECTION**
1.1	Site location: safe and sustainable
1.2	Conservation of pre-existing landscape
1.3	Proper orientation according tosun and wind
1.4	Waste management&recycling on site
1.5	Landscape improvement(planting trees, water free vegetation…)
1.6	Restoration of landscape after use
2	**MATERIALS**
2.1	Use of local materials
2.2	Easy maintenance and upgrade of materials
2.3	Reuse of materials
2.4	Use of recycled materials
2.5	Use of earth materials and low embodied energy materials
2.6	Use of non toxical&non contamining materials
2.7	Use of low impact construction methods
2.8	Support of sustainable and legal sourcing materials
2.9	Use of fewer materials
2.10	Use of thermal mass
2.11	Reuse or recycling of shelter materials after lifespan use
3	**ENERGY EFFICIENCY AND RENEWABLE ENERGIES**
3.1	Use of solar power
3.2	Use of solar thermal energy(domestic hot water)
3.3	Use of wind energy
3.4	Use of other renewable energies(geothermal,biomas..)
4	**WATER EFFICIENCY**
4.1	Collection and use of rain water or use of recycled water
4.2	Use and reuse of ground water
4.3	Low flow toilets or non using water toilets
5	**INDOOR COMFORT**
5.1	Daylight provision
5.2	Proper natural ventilation
5.3	High efficiency lamps and HVAC
5.4	Optimization of glazing systems
5.5	Use of sustainable insulation

3.2.3 Main criteria and sub-criteria description

3.2.3.1 Site selection

The main objective is to limit the environmental impact of the shelter or shelter settlement on local ecosystems, preserving and improving the health and welfare of the surrounding communities.

– **Site location: safe and sustainable.** Emergency shelters are usually built in groups known as settlements. These settlements should be located in sites that minimize the exposure of the occupants to hazards and maintain access to livelihoods. An assess on soil characteristics is recommended. This provides important information for determining a suitable site, in case foundations drilling water wells are needed. Settlements should avoid to be built next to dangerous structures. Emergency shelters should not be built on land liable to flood or landslide. A shallow slope to allow for drainage is ideal. The emergency shelters should be located outside of hazardous and environmentally fragile areas to avoid contaminating area.

– **Conservation of pre-existing landscapes**. When the settlements are not located in urban areas but in natural sites, the site design and construction process should start with landscape mapping prior to site clearance. The resulting data should be used to the extent possible to integrate site plans into the natural landscape rather than to design the natural landscape to fit the site. Maintaining existing vegetation and habitats will improve environmental conditions by, for example, providing natural shade to reduce solar heating, retaining access to indigenous sources of food and medicine, and providing more pleasant living conditions. Special care has to be taken to avoid disturbances to sensitive and/or protected local flora/fauna. Indigenous vegetation is also usually more resistant to local hazards and more resilient following disasters than is exotic vegetation. Selecting indigenous plants (technique known as xeriscaping) could reduce water requirements more effectively than low flow fixtures or sensor operated faucets.[41]

– **Proper orientation according to sun and wind**. Design for orientation is a fundamental step to ensure that emergency shelters work with the passage of the sun across the sky. A careful strategy and knowledge of sun paths for any selected site is fundamental in design of shelter facades to let in light and passive solar gain, as well as reducing glare when sunshine is excessive and mitigate overheating to the emergency shelter interior. Well-orientated settlements maximize day lighting through shelter facades reducing the need for artificial lighting. Emergency shelters that maximize sunlight are ideal for the incorporation of passive solar collection techniques that can reduce fossil fuels use and enhance user comfort.

– **Waste management and recycling on site.** Solid waste disposal should be planned and implemented in close consultation and coordination with the affected population and relevant agencies and authorities. This process should start in the beginning of the intervention before a solid waste problem becomes a major health risk to the affected population. Waste disposal strategies and periodic clean-up campaigns need to be organized in consultation with the population and responsible local authorities.

Appropriate waste collection reduces public health issues. In designing appropriate strategies, the following should be taken into account:

- Already available means for waste collection
- Accessibility of waste collection points
- Waste disposal procedure
- Involving affected population in system design
- Segregation of waste into various waste streams and treating appropriately
- Promotion of reduction, re-use and recycling of materials

– **Landscape improvement.** Considering carefully the landscape design with special emphasis on the size of the space that are dedicated to plant groups (trees, plants and grass, etc.), types of the plants and micro-climate characteristic of the selected site, an approach as calculation for reducing the watering must be done.

The design should include a planting program and an irrigation system. Furthermore, adequate site drainage must be provided to minimize the risk of flooding. Individual emergency shelters must be connected to site drainage solution.

– **Restoration of landscape after use.** All interventions in the settlement site should incorporate components to restore disturbed environments to pre-project conditions where possible. These efforts should include areas from which natural resources have been extracted and the clearing and restoration of construction sites. While a new emergency shelter settlement does change the local environment, this change should be minimized by later restoration of the natural environment whenever possible after the end of the settlement lifespan.

3.2.3.2 Materials

The main objectives are to make an appropriate selection and management of materials with minimal environmental impact.

– **Use of local materials.** Use local sources where this can be done in a sustainable way. Local procurement of materials can be a more environmentally strategy than the procurement of distant materials because of the savings in transportation costs, packaging, and energy involved and carbon footprint. When using local materials, however, it must be made sure that extraction, processing, and use do not put people's health or environment at risk.

Materials used in the project, must be obtained on or near the site for construction. Care must be taken to ensure that non-renewable earth materials are not over-extracted. Ecological balance within the region needs to be maintained while efficiently utilizing its resources. Many local suppliers carry materials that have been shipped in from out of the area, so it is important to ask for locally produced/quarried materials.

– **Easy maintenance and upgrade of materials.** There must be a consideration of the energy used in the manufacturing of the materials used, the energy consumed over their life -and the emissions produced during maintenance, repair and replacement. Also only must be considered materials with an easy cleaning without chemical products that could potentially damage the environment.

– **Reuse of materials.** Materials such as concrete, metals, glass, brick and plastics can all be produced with some form of the previously used material, and this process of production lowers the energy requirement and emissions by up to 90% in most cases. Reusing materials from existing on site and nearby site elements such as trees, structures, and paving is becoming a trend in the built environment. It is important to recognize that the sustained growth in reuse efforts, as well as the sustained interest of the reuse industry, derives in large measure from the solid waste reduction hierarchy: Reduce, Reuse, and then Recycle. It is best to reduce first, reuse as a second option, then to resort to recycling. The most environmentally sustainable option for resourcing shelter materials is the reuse of waste building materials in their existing state without downgrading and reprocessing into new products. Massive amounts of materials can come from disaster debris and demolition sites. The potential for using these materials is enormous; they mitigate the need to buy new materials and prevent the consumption of energy in moving debris to landfill areas. The steel, bricks, timber, and tiles that are left after a disaster can often be used to provide transitional shelter to affected families, and can serve as the starting point for reconstruction.

– **Use of recycled materials.** This includes 2 criteria: use of already recycled materials for shelters and the recycling of the materials after the use of the shelter. There should be a tendency to use materials with recycled content. For example, fly ash from coal-fired power plants can be incorporated into cement production. This will help to reduce demand on natural resources and lower the human and environmental impacts. The incorporation of wastes from agriculture and industry as raw materials and as fuel substitutes, reduces pollution and the need for the extraction of new raw materials.

– **Use of earth materials and low embodied energy materials.** Earth is a 100% eco-friendly construction material. It is neither manufactured nor transported. A wall made from raw earth serves as a natural air conditioner, being warm in winter and cool in summer. When the shelter is demolished, the earth returns to the soil and can be recycled indefinitely.

Materials selected for the shelter should tend to have low embodied energy, use less energy and fewer resources to make, transport and build. These are much kinder on the environment as they use fewer resources which are often non-renewable, and they produce fewer greenhouse gas emissions.

Unfortunately, the lowest-embodied-energy solutions are generally those involving materials such timber, which is becoming increasingly scarce. However, secondary species of timber available from well managed forests, such as rubber and coconut, among other kinds, can provide a sustainable supply. Technologies for protection against biodegradation and preserving the dimensional stability (i.e., the ability of wood to retain its form when exposed to moisture) of these species are already available and are cost effective. Also, new lightweight or hollow blocks, fiber-concrete products, and other composites can save energy compared with more conventional products.

– **Use of non toxical materials and non contaminating materials.** Eliminate the use of materials that pollute or are toxic during their manufacture, use, or reuse. Use of structural materials that do not require application of finish. Use of non toxical isolation.

Within an acceptable category of product, use materials and assemblies with the lowest level of volatile organic compounds (VOCs). Elimination of the use of asbestos, lead, and PCBs in all products and assemblies. Elimination of the use of chlorofluorocarbons (CFCs) and hydro chlorofluorocarbons (HCFCs) as refrigerants in all HVAC systems. Selection of paints, coatings, plastics, rubbers and seals that are free from flame retardants and/or softeners containing PBDEs and HBCD. Avoid product coatings that contain fluorotelomers based on C8 or higher fluorocarbon chemistries. Selection of textiles, paints, printing inks, and paper that are free of benzidine and benzidine congener-based dyes. Use of detergents that do not contain NPE and APE surfactants. When possible, preference given to products that openly discloses substances used in the manufacture of a product and substances comprising the final product. Avoid Ground-level Ozone in shelters. It can contribute to health problems for the shelter's occupants and damages vegetation and ecosystems.

– **Use of low impact construction methods.** These include, for example, those requiring minimal land clearance or those designed to reduce energy requirements for heating or cooling. Where possible, construction methods should be based on locally available skills and competencies, and minimize the need for imported labor and skills.

– **Support of sustainable and legal sourcing materials.** In large-scale, post-disaster projects, the demand for raw materials can quickly outstrip the supply of sustainably produced natural resources, such as clay for bricks, sand for cement, and wood for timber. This situation produces collateral devastation that was not directly created by the disaster. For example, unsustainable excavation of clay from hillsides to rebuild houses increases the risk of landslides and topsoil erosion, which can lead to the pollution of water and negatively impact livelihoods and human health. Such environmental damage can increase risk and jeopardize the success of the overall recovery effort. Using materials that have been officially certified is one strategy for ensuring that materials have been sourced sustainably. Procurement of materials should not be based only on cost, time, and availability criteria, but also on verification that the source of material is legal and sustainable, while simultaneously seeking to minimize energy used for the transportation.

– **Use of fewer materials.** While designing shelters there has to be a consideration of ways to effectively meet humanitarian needs with fewer materials. This can be done with design strategies such as using cavity walls in place of solid masonry walls or ribbed slabs in place of solid concrete slabs where feasible. Designing structures with standard material sizes can also help to prevent waste of materials during the construction phase.

– **Use of thermal mass.** Thermal mass is the mass in the shelter envelope (walls, floor and roof) that is used to absorb heat during the day and then to release the heat as the shelter cools in the evening. Materials with a high thermal mass are energy efficient, especially if the outdoor humidity is not so high. For example, a thick plaster layer on straw bale walls provides considerable mass, which can then be augmented with an exposed concrete, adobe, or other high-mass floor; adobe seating, masonry; or water tanks. Stone wall facings or partitions increase working thermal mass. The more thermal mass, the more stable the temperature of the emergency shelter. However, exterior insulation is still needed to prevent overheating in the summer and chilling in the winter.

– **Reuse or recycling of shelter materials after lifespan use.** The recycled material of an emergency shelter is defined as a material which can be remade and re-used as a building material after the emergency shelter is disassembled. It is called ‘‘recycled’’ when the product partly or totally manufactured from the disassembled materials. The method of processing recycled material can be classified into three types: product recycle, material recycle, and feed-stock recycle. ‘‘Production recycle’’ refers to a process where the product can be used again, without changing the form/nature of the material. ‘‘Material recycle’’ is a process that, after it is separated/collected, the disassembled material is processed into a building material. ‘‘Feedstock recycle’’ refers to a process where the disassembled material is processed into feedstock to make a building material.[42]

3.2.3.3 Energy efficiency and renewable energies

The main objectives are to reduce the amount of energy required by the shelter and find sustainable alternatives for power generation.

- **Use of solar power.** To balance the shelter's energy cost, use of renewable energy systems is recommended. Solar energy can be collected by individual emergency shelters through installing solar panels that convert this energy into electricity. Photovoltaic materials are now available for virtually all surfaces of the emergency shelter envelope. For example, photovoltaic shingles, metal standing-seam, exterior insulation systems for the roof, solar-collecting spandrels, insulated glass units, sunshade elements, etc. Photovoltaic-generated electricity can be used as is, stored in a battery for later consumption, or, in the most common scenario, converted to alternating current (AC) by an inverter. The AC power could be used by the emergency shelter. Excess electricity can then be stored in a battery or can be sent back into the grid, if the settlement is tied into the electrical grid. Estimating the potential energy consumption of the shelter and then the renewable technologies should be determined with sufficient anticipation to compensate to a certain extent the costs of emergency shelter energy.
- **Use of solar thermal energy.** Shelters can be planned to contain built -in solar features that aid in generating, heating and cooling. This type of system is ideal for semi temporary shlters that become permanent as its free after the initial investment and is virtually maintenance free. Solar energy collectors are another way that solar energy can be exploited. This system works by using solar radiation to heat an absorber plate which then heats the water running through tubes within the collector. The hot water can then be used to heat the emergency shelter in the winter.

Ventilation and cooling can also be achieved through solar energy. A solar chimney as part of the architectural design would be useful to capture this energy. Air inside the chimney is heated by solar energy, creating an updraft as the hot air rises. The updraft pulls air from the attached shelter up and out, thereby providing ventilation. When air conditioning is needed, cooling can be accomplished when the updraft created by the solar chimney pulls cool air up from heat exchange tubes located underground.

Including these features in emergency shelters would be beneficial both to the environment and the individuals or communities living in. Using solar energy to generate domestic heat water could lead to huge savings in energy costs. Solar power is renewable and sustainable and doesn't produce any greenhouse gas emissions, reduces dependency on fuel therefore it will not damage our environment.

– **Use of wind energy.** A wind turbine is a rotary device which utilizes mechanical energy and converts it into electrical energy. Windmills that extract the energy from the wind and utilize the mechanical energy for cutting of lumber, pumping water etc have been used since ancient times. And after the industrial revolution, the concept of using the wind power with the help of wind turbines to generate electricity was discovered.

If the mechanical energy is instead converted to electricity, the machine is called a wind generator, wind turbine, wind turbine generator (WTG), wind power unit (WPU), wind energy converter (WEC), or aerogenerator.

The wind turbines cannot be installed anywhere. They require a suitable location for their erection and their proper functioning. For smaller buildings like emergency shelter microturbines can be installed.

The orientation and location of the emergency shelter should not create a problem for the installation of a wind turbine. It should preferably be located in the direction of the wind so that it can capture enough wind energy so as to convert it into mechanical energy.

– **Use of other renewable energies.** Naturally-occurring hot water and steam can be tapped by energy conversion technology to generate electricity or to produce hot water for direct use. In order to maximize the energy gleaned from these so-called "hot dry rocks," geothermal facilities will often fracture the hot rocks and pump water into and from them in order to use the heated water to generate electricity.

The term "biomass" refers to organic matter that has stored energy through the process of photosynthesis. It exists in one form as plants and may be transferred through the food chain to animals' bodies and their wastes, all of which can be converted for everyday human use through processes such as combustion, which releases the carbon dioxide stored in the plant material. Many of the biomass fuels used today come in the form of wood products, dried vegetation, crop residues, and aquatic plants. Biomass has become one of the most commonly used renewable sources of energy in the last two decades, second only to hydropower in the generation of electricity. It is such a widely utilized source of energy, probably due to its low cost and indigenous nature, that it accounts for almost 15% of the world's total energy supply.

3.2.3.4 Water efficiency

The main objective is to limit or reduce the use of potable water and wastewater generation.

– **Collection and use of rain water or use of recycled water.** Depending on rainfall frequency, roof type, air pollution, dust levels, and collection tanks available, rainwater can be a very healthy drinking water option for local communities. In the humanitarian aid context, the typical rain tank setup includes rooftop collection and a storage chamber. Responsible stormwater management will contribute to reduce the use and waste of potable water.

– **Use and reuse of groundwater.** Groundwater sources are often used as potable water sources. Most often hand-dug wells are used for this purpose, with water collection done through a simple pulley and rope mechanism. During the design phase for a groundwater pump, it is critical that the recharge rate of the aquifer be tested to determine if it has the capacity for sustained pumping. This must be done to ensure that the withdrawal rate does not exceed the recharge rate.

– **Use of low-flow toilets or non using water toilets.** Conventional toilets can use as much as 23 litres of water per flush. A low-flush toilet or low-flow toilet is a flush toilet that uses significantly less water than a full-flush toilet. Most low-flush toilets use just 6 liters of water.

3.2.3.5 Indoor comfort

The main objectives are to provide comfort and well-being of occupants of the shelter and to guarantee a suitable comfort conditions for the use of the housing.

– **Daylight provision.** Strategies and approaches must be developed to benefit from shelter orientation, passive energy use and sun. To provide effectively natural lighting, on the early stages of design daylight simulations are required. If any topography and vegetation exits near the shelter, they must be protected for their shading minimizing glare. The distribution of space within the emergency shelters must be well evaluated, frequently and regularly used spaces should be placed close to the outer shell of the emergency shelter.

Overheating of the emergency shelter prevents efficient use of energy. For this reason, for benefiting the daylight, wall openings (windows, etc.) number and surface shouldn't be increased a lot. In addition, strategies should be developed to control the effect of glare from windows.

– **Use of proper natural ventilation.** Design of the emergency shelter to allow for adequate ventilation and minimize internal temperatures. Where possible, promote openings on 3 sides of the post-disaster housing to allow for cross ventilation. Proper window placement and interior design can capture cool breezes in the summer and increase comfort significantly. Insulated screened vents can be more economical than operable windows. Doors and windows placed at the front and rear of each emergency shelter make use of natural cooling. Openings should be well distributed and should be located on the windward side at a low level. Interior airflow can be improved if the doors are cut 2 or 5 cm. above the floor level, and if vents and windows are placed above the doors. In hot climates, raised floors and high ceilings increase ventilation and improve comfort. Cool air for ventilation can be drawn from shaded areas near the ground and from landscaping, which tends to stay cooler in hot climates.

– **Use of high efficiency lamps and HVAC.** Many simple upgrades can be made with reasonable results to existing systems and standard specifications. The easiest way method for reducing the energy used to provide lighting is to invest in compact fluorescent lights, as opposed to traditional incandescent lights. Compact fluorescent lights use approximately 75 percent less energy than typical incandescent lights.[43]

Other options for saving energy are: installing fluorescent lighting systems in place of incandescent lighting systems or installing metal halide or high-pressure sodium vapor lamps in place of mercury vapor lamps.

LED technology offer lifespans of 30,000 or more hours and LED bulbs use 85% less energy and last up to 20 years longer than incandescent bulbs.[41]

– **Optimize energy performance of glazing systems.** Virtually every emergency shelter has window systems of some type. Selecting and specifying windows and glazing certainly has a significant impact on the overall design and aesthetic of a shelter but equally important is the overall quality of the window system in terms of durability, weather resistance and physical integrity.

Understanding the differences between these three choices and their respective strengths and weaknesses will allow best performing system for an individual emergency shelter design.

– **Use of sustainable insulation.** Although a proper orientation of the shelter is the first step of design, insulation is also necessary to save the heat from sunny winter days for cold nights. Thick mud walls, for example, are well suited to arid desert climates with high daytime temperatures and low nighttime temperatures because of the slowness in their thermal-transfer qualities. The walls of straw-clay also provide excellent insulation and allow for exceptional comfort and performance in extreme environments. Use insulation only for roofs exposed to direct solar radiation. Protect structures from excessive heat gain by using appropriate insulation materials. For example, mineral wool can be used for under-deck roof insulation. Resin-bonded mineral wool is available in the form of slabs and rolls. Or, instead of roof insulation, a shaded roof, helps to reduce heat ingress.

4. EVALUATION OF ENERGY EFFICIENCY AND SUSTAINABILITY OF SELECTED EMERGENCY SHELTERS

4.1 Introduction of the Case Study Emergency Shelters

According to the definition given by Corsellis and Vitale (2005) a shelter "provides a habitable covered living space and a secure, healthy living environment, with privacy and dignity, for those within it, during the period between a conflict or natural disaster and the achievement of a durable shelter solution".[44]

Following a disaster, people whose homes have been damaged or destroyed, or who have been displaced as a result of the disaster, will need cover and protection against the external conditions. This primal human need is met in the first phase by fixing their damaged home or by temporary shelters using local materials or provided by governments or humanitarian organizations.

If a shelter design is appropriate, it reflects the needs, local culture, vulnerability and capacities of the affected community and the resources available. Also it will address sustainability on its design, construction and use.

To understand the state of the art of emergency architecture on the fields of energy efficiency and sustainability, an analysis of proper representative examples must be conducted.

Within this chapter, a research of the energy performance of emergency shelters in different climates is conducted. Three emergency shelters have been selected from three different locations around the world to study their energy performance when applied in Turkey. A simulation in different climates is performed in order to provide a wide range analysis, on a local scale, of the case studies.

The following criteria were used to select the case study emergency shelters:

- Significant numbers of this emergency shelters have been built and were used in real post-disaster situations.
- All of the emergency shelters have been involved in an earthquake disaster situations so they can be relatable to Turkey main disaster threat.
- Accurate technical information was available for all the emergency shelters.

– All of the emergency shelters had the following common characteristics: space for a family of 4/5, constructed area around 18m2 (based on a minimum of 3.5m2 covered living space per person for a family of 5), one storey and simple construction.

– Each emergency shelter is selected to cover the widest range of options used in real situations and each of them represents one of the main typologies by material used in emergency situations: wood envelope typology, plastic envelope typology and metal envelope typology. Materials such bricks and concrete were not considered as they aim to be used in semi-permanent or permanent solutions.

– Each emergency shelter was able to last the entire transitional period until durable solutions were available.

– The emergency shelters were appropriate for the people for whom they were built. They also, encouraged some form of efficiency of design, and could withstand local hazards.

– The shelters used materials which could be incorporated into longer term recovery shelter options.

– The shelters presented one or several sustainable strategies.

Based upon the aforementioned criteria, and after the research conducted, the selected emergency shelters are:

– **Wood envelope typology**. An 18m2 shelter with timber framed structure and palm roofing and wooden walls used in the 2009 Sumatra earthquake, as seen in Figure 4.1.

Figure 4.1: Wooden shelter in Padang, Sumatra island, Indonesia (2009) [45]

– **Plastic envelope typology**. An 18m2 shelter with steel structure and plastic wall sheeting attached, used in the 2010 Haiti earthquake, as seen in Figure 4.2

Figure 4.2: Plastic shelter in Haiti (2010) [45]

– **Metal envelope typology.** A prefabricated emergency shelter made of reinforced aluminum profile frame and walls and roof from polyurethane filled metal panels used in the 2011 Van earthquake, as seen in Figure 4.3.

Figure 4.3: Prefabricated metallic shelter in Van, Turkey (2011) [45]

As every context is different, so shelter designs must be adapted to each location, and specific disaster. What might be a good solution in one location may not work in another. However, one of the key features of these shelters is that they can be relocated, they can be upgraded and that the materials can be re-used.

For the purpose of this study, these three emergency shelters have been selected from three different locations around the world to study their energy and sustainable performance when applied in Turkey. Turkey is an ideal field for the study because:

– It is a country particularly prone to earthquakes (in the range of magnitude 7) and frequently experiences housing problems after every disaster, being a very suitable field for post-disaster housing research.

– Presents a wide diversity of climatic regions that can be partly extrapolated to other regions prone to disasters.

– The current emergency shelter solutions available for post-disaster situations are inadequate tents

The three case studies are located in five cities that correspond with five different climatic regions in Turkey:

- Istanbul: Temperate humid
- Ankara: Temperate Dry
- Van: Cold humid
- Mugla: Hot humid
- Diyarbakir: Hot Dry

Figure 4.4 shows the five different climatic zones of Turkey and the location of the five cities selected to simulate the emergency shelters.

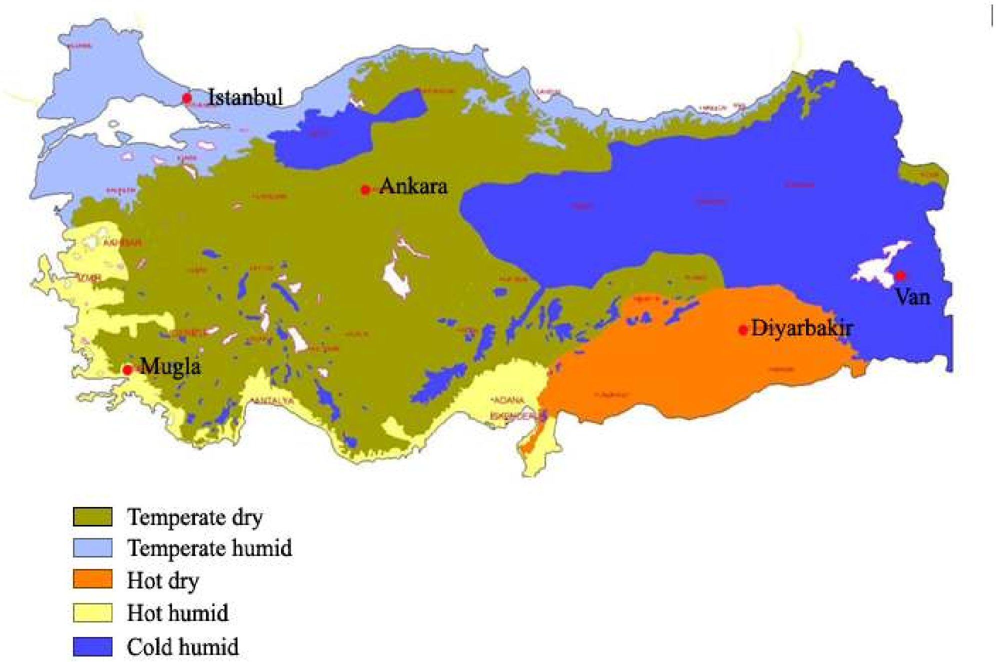

Figure 4.4: Climatic map of Turkey [46]

Detailed values of the location of the five cities are given in the following Table 4.1

Table 4.1: Latitude, longitude and altitude values of the five cities selected

City	Latitude (ºN)	Longitude (ºW)	Altitude (m)
Istanbul	41	28,5	23
Ankara	39,5	32,5	891
Van	38,2	43,2	1750
Mugla	37,1	28,2	660
Diyarbakir	37,9	40,2	686

The detailed description of the climatic characteristics of each city is as follows.

– **Istanbul:** In summer the weather in Istanbul is hot and humid, the temperature between June and September averaging 28°C. Rain does occur all year round. During winter it is cold, wet and often snowy. Snowfalls tend to be heavy, but temperatures rarely drop as low as freezing point. Istanbul also tends to be a windy city.[47]

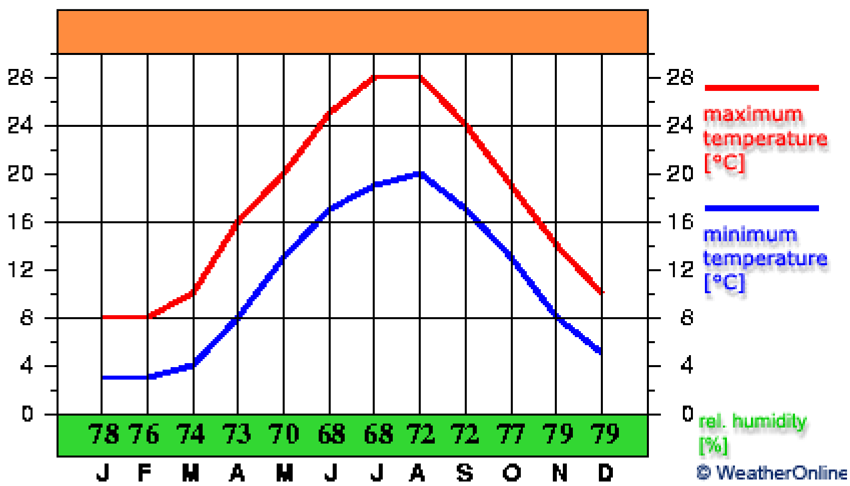

Figure 4.5: Istanbul climate graph with yearly max/min temperature and relative humidity [48]

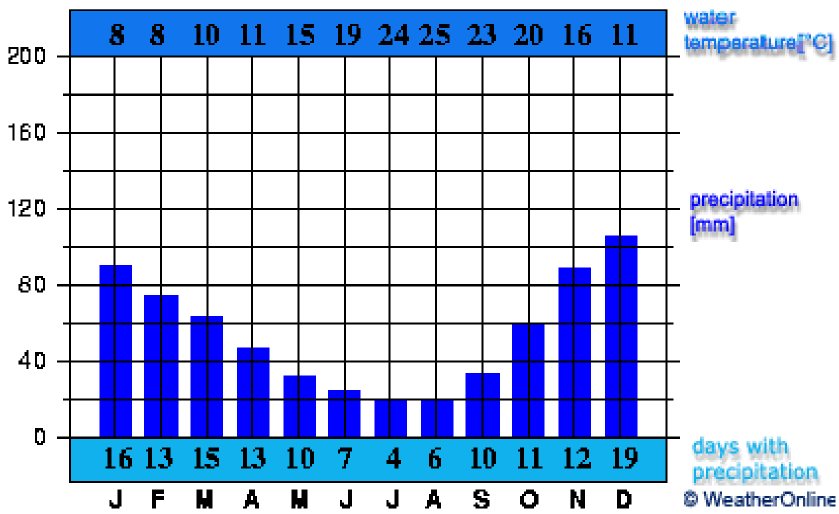

Figure 4.6: Istanbul graph of yearly precipitation [48]

– **Ankara:** the climate of Ankara is relatively mild and continental, with the annual seasons remaining quite distinctive and easy to differentiate. The winter weather in Ankara is quite short, although often quite cold, frosty and at times with snow. In the summer climate the days are often long, sunny, dry and pleasantly hot.

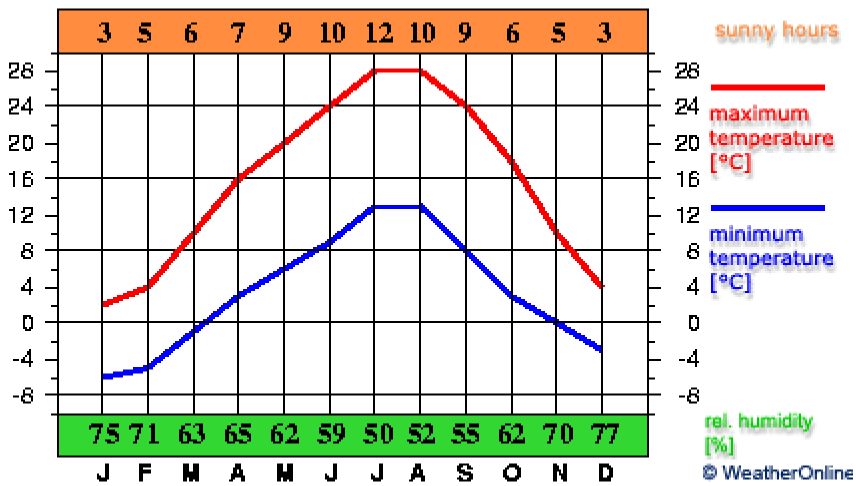

Figure 4.7: Ankara climate graph with yearly max/min temperature and relative humidity [48]

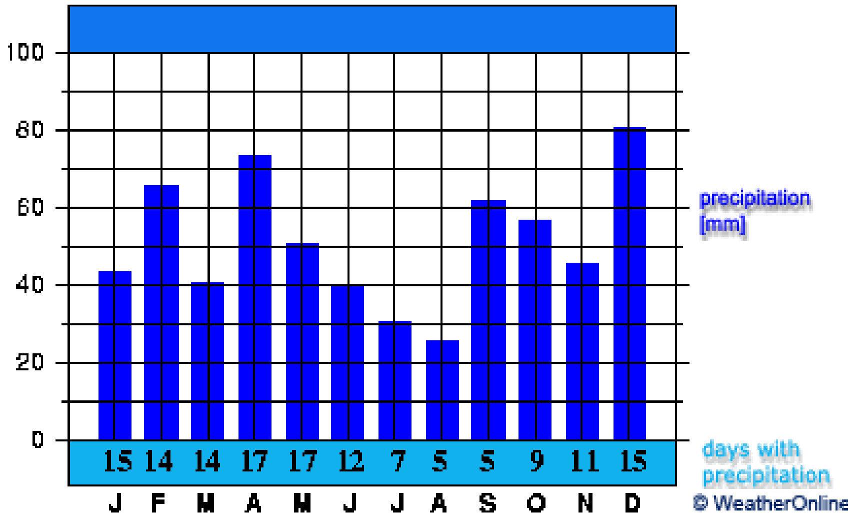

Figure 4.8: Ankara graph of yearly precipitation [48]

– **Van:** Van has cold, snowy winters, and hot, dry summers. Over the course of a year, the temperature typically varies from -7°C to 28°C and is rarely below -13°C or above 30°C. Rainfall occurs mostly during the spring and autumn.

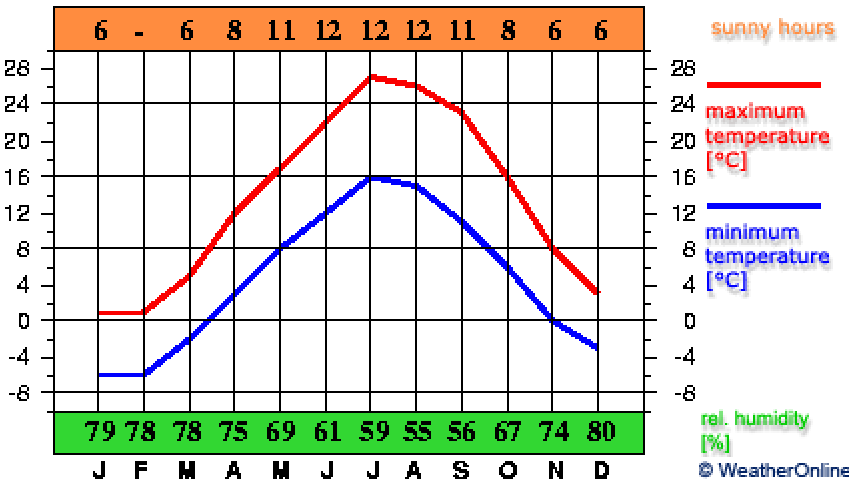

Figure 4.9: Van climate graph with yearly max/min temperature and relative humidity [48]

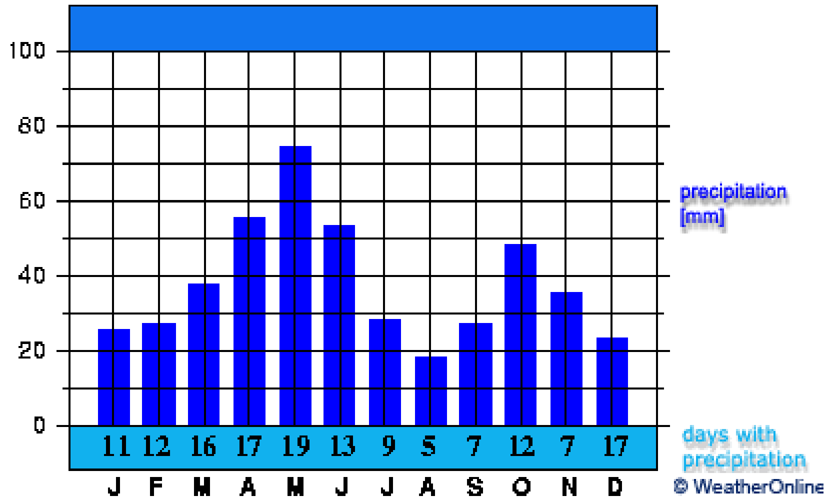

Figure 4.10: Van graph of yearly precipitation [48]

– **Mugla:** It is under the effect of the Mediterranean climate, characterized by long, hot and dry summers with cool and wet winters. The average annual temperature is 14.9°C.

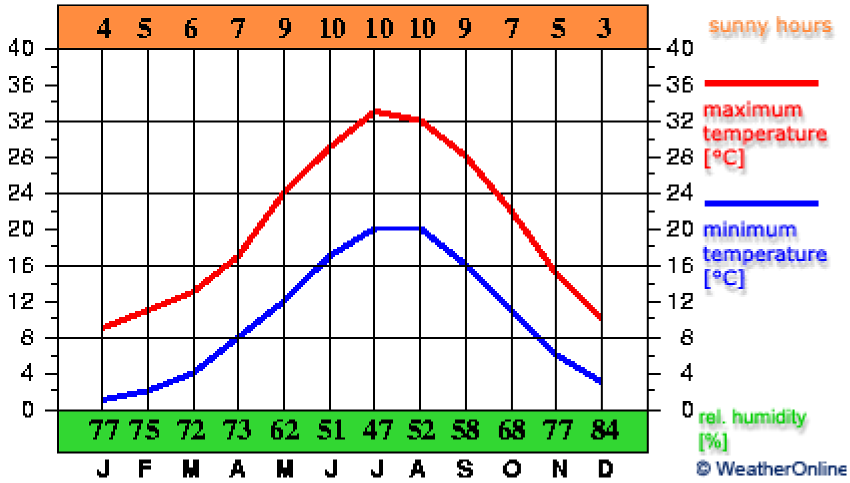

Figure 4.11: Mugla climate graph with yearly max/min temperature and relative humidity [48]

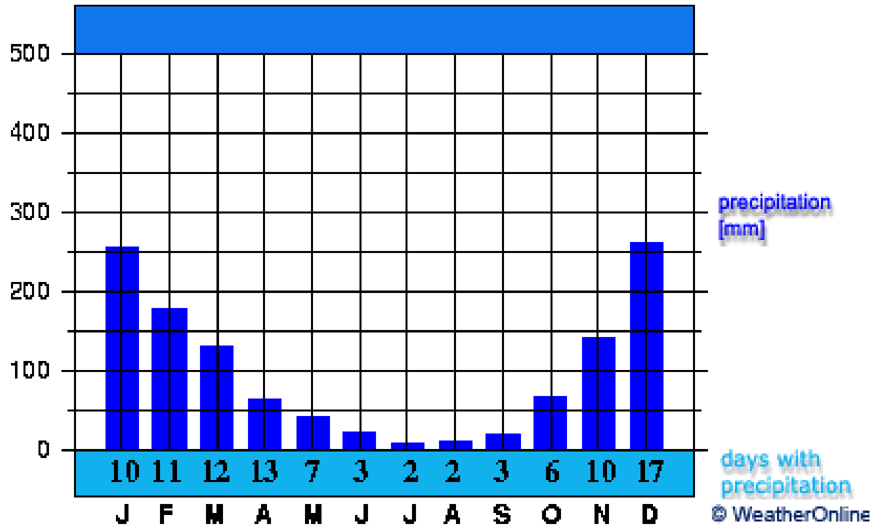

Figure 4.12: Mugla graph of yearly precipitation [48]

– **Diyarbakir:** Summers are very hot and very dry, due to its location on the Mesopotamian plain which is subject to hot winds from the deserts of Syria and Iraq to the south. The highest recorded temperature was 44.8°C on 28 August 1998. Winters are cold and wet and with frosty nights. Snowfall is quite common between the months of December and March, snowing for a week or two. The lowest recorded temperature was −23.4°C on 30 December 2006.

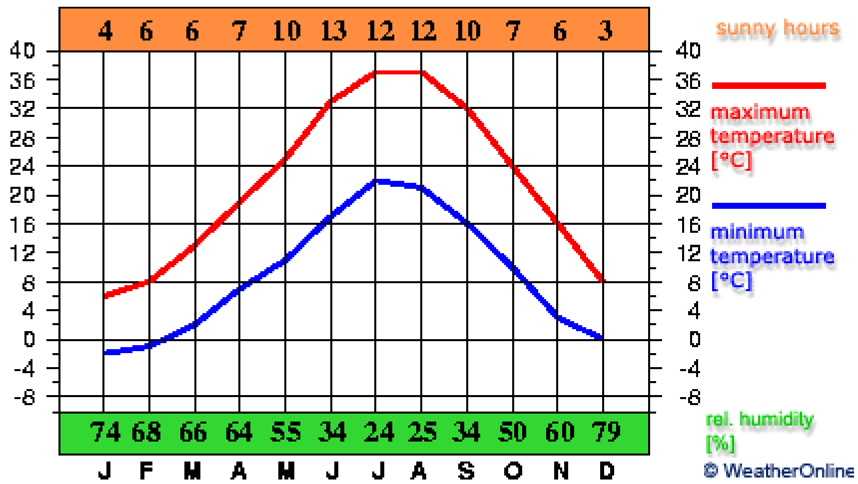

Figure 4.13: Diyarbakir climate graph with yearly max/min temperature and relative humidity [48]

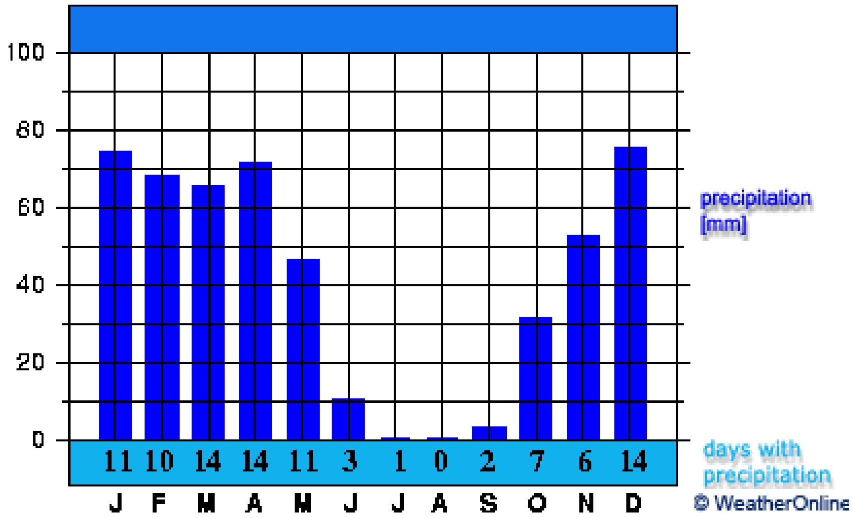

Figure 4.14: Diyarbakir graph of yearly precipitation [48]

In a real disaster situation projects must take into consideration the local contexts and needs of the affected population, which will differ in every case. Projects should not be directly copied instead they should be locally adapted or there will inevitably be programmatic weaknesses and failures.

The selected designs do not claim to be the best examples of such shelter solutions. The case studies selected illustrate a diversity of approaches to meet shelter need. Providing shelter is more than simply designing architecturally impressive structures. These case studies provide an immediate range of options to inform governments, organizations and individuals involved in shelter design and provision. Other materials such bricks, concrete blocks or earth blocks has been discarded as they are considered materials used for the construction of semi-permanent or rather permanent shelters.

4.2 Energy Performance Simulation Parameters

For the purpose of this study, the three emergency shelters selected are simulated in five different climatic zones of Turkey. The program Design Builder is used to carry out the energy performance simulations. This program is a software tool for checking building energy, carbon, lighting and comfort performance.[49] Design builder is a comprehensive user interface to the Energy Plus dynamic thermal simulation engine that provides accurate environmental performance data.

The following assumptions are made in the simulation of the three emergency shelters:

- In a first phase, in chapter 4, the 3 case study emergency shelters selected are simulated without the use of mechanical systems (heating, ventilation and air conditioning) to provide indoor comfort. The simulation aims to be faithful to the real state of the emergency shelters that only use passive resources (envelope, natural ventilation and solar gains) to provide indoor comfort.
- In a second phase, in chapter 5, emergency shelters are simulated with mechanical systems in order to compare their energy consumption.
- The occupancy is simulated as 5 people living in an emergency shelter of 18m2. The density of occupation of the emergency shelter is the number of people per m2. The density is assumed 0.27.
- The metabolic rate, according to the ASHRAE 55-2010 Standard is the level of transformation of chemical energy into heat and mechanical work by metabolic activities within an organism, usually expressed in terms of unit area of the total body surface. In the standard, metabolic rate is expressed in MET units (1 MET = 58.2 W/m²) which is equal to the energy produced per unit surface area of an average person seated at rest. The surface area of an average person is 1.8 m².[50]The factor used in this simulation is 0.90 according to the values are 1.00 for men, 0.85 for women and 0.75 for children.
- Main facade is orientated south to better maximize solar gains.
- The openings in all the emergency shelters are simulated as being the same, in the same position and size, in order to the natural ventilation to be equal.

Within the scope of this study, the simulation of the emergency shelters aims to have objective numerical results to compare the following factors:

- **Operative temperature:** a uniform temperature of a radiantly black enclosure in which an occupant would exchange the same amount of heat by radiation plus convection as in the actual non-uniform environment. In design, operative temperature can be defined as the average of the mean radiant and ambient air temperatures, weighted by their respective heat transfer coefficients.

Mathematically, operative temperature (T_o or T_{op}) can be expressed as the Equation 4.1;

$$T_o = (h_r \, . T_{mr} + h_c \, . T_{db}) / (h_r + h_c) \quad \textbf{(4.1)}$$

h_c : convective heat transfer coefficient, W/(m^{2}K)

h_r : linear radiative heat transfer coefficient, W/(m^{2}K)

T_{db} : air (dry bulb) temperature, ºC

T_{mr} : mean radiant temperature, ºC

The operative temperature is applied to find the thermal comfort within the emergency shelters, the thermal experience of the users in the interior of the space.

– **External infiltration:** heat gain and loss through air infiltration (non-unintentional air entry through cracks and holes in building fabric) when using simple natural ventilation, typically expressed in cubic feet per minute (CFM) or liters per second (LPS).

– **Solar gain:** increase in temperature in a space, object or structure that result from solar radiation. In the context of passive solar building design the aim of the designer is normally to maximize solar gain within the building in the winter (to reduce space heating demand), and to control it in summer (to minimize cooling requirements).

4.3 Evaluation of Wooden Emergency Shelter

In September 30, 2009 a 7.9-magnitude earthquake struck 57 km southeast of the city of Padang in the Indonesian island of Sumatra, followed by a second earthquake. On October 1st in the near Jambi province.[51]

The fatalities reached 1.115 while seriously injured ascended to 1.214.[52]

The earthquake brought down hospitals, schools and shopping malls, cut power lines and almost 300.000 houses were either destroyed or damaged. The priority humanitarian needs included emergency shelter, water, sanitation and hygiene, food and nutrition, education and health. As a part of the humanitarian response, the Red Cross provided temporary shelters that were constructed for homeless families in the cities of Padang and Pariaman.[53]

4.3.1 Wooden emergency shelter description

The shelter is a timber framed structure with palm roofing and plywood walls. It measures 4.5m x 4m on plan (18m2) and is 3.35m tall to the ridge beam and 2.4m to the eaves. It has a pitched roof of 23.6 degrees.

The shelter has a suspended floor. This is assumed to be coconut wood boarding spanning between the floor joists. The columns are embedded into concrete bucket foundations that sit directly on the ground.

The materials cost per shelter is $375 and the project cost per shelter is $535.[42]

The number built was 7.000 with an anticipated lifespan of 6-12 months.

Figure 4.15: Wooden emergency shelter and earthquake location [45]

4.3.2 Wooden emergency shelter construction and materials

The shelter is constructed from locally procured materials that are familiar to the occupants and do not require special tools or equipment for assembly. The materials are timber frame for the structure, plywood walls, palm fiber roof and palm matting. It can be quickly constructed in 2 days with a construction team of 5 people. Is simple to maintain and adapt over time, depending on the needs of the occupants. This shelter offers a good short term design solution that is appropriate in areas vulnerable to high seismic and wind loading.

In the Figure 4.16 is shown the construction plan and section with structural dimensions.

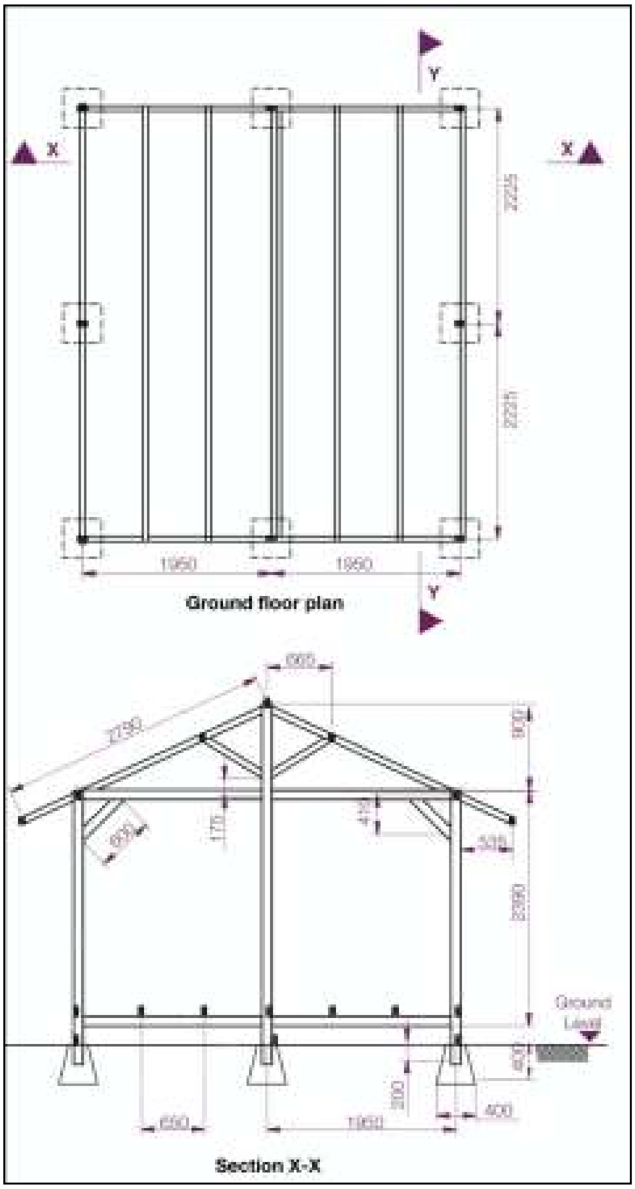

Figure 4.16: Wooden shelter plan and section [45]

In Figure 4.17 is shown an axonometric of the structure with the technical names used to design each part of the emergency shelter.

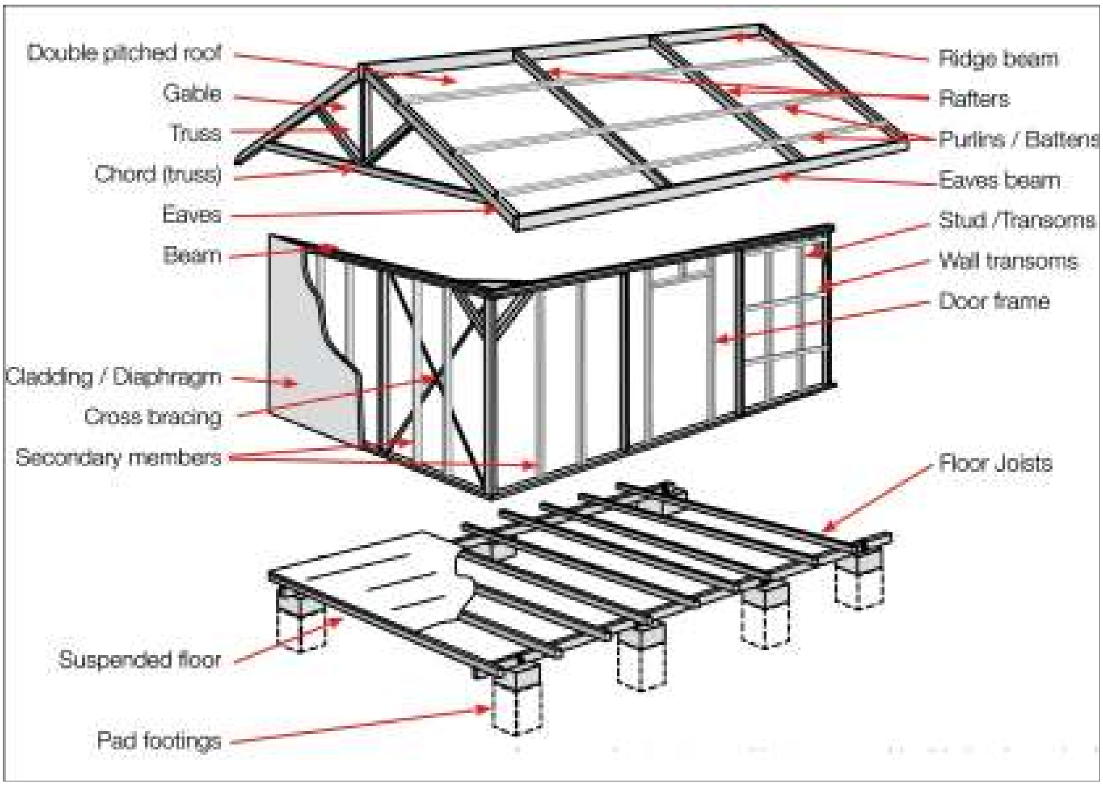

Figure 4.17: Wooden shelter structure [45]

4.3.3 Green evaluation checklist

Within the scope of this study, the evaluation using the approach of a green rating system focuses on the materials and energy efficiency and renewable sections. The section of site selection is not included as the emergency shelters selected are abstracted to be in the five climate regions of Turkey in a simulated site. The sections of water efficiency and indoor environment are not included for the lack of verifiable information.

In the following Table 4.2 it is shown the green checklist results for this emergency shelter.

Table 4.2: Wooden emergency shelter green rating

MATERIALS	YES	NO	No information
Use of local materials	1		
Easy maintenance and upgrade of materials	1		
Reuse of materials		1	
Use of recycled materials		1	
Use of earth materials and low embodied energy materials	1		
Use of non toxical&non contamining materials	1		
Use of low impact construction methods	1		
Support of sustainable and legal sourcing materials	1		
Use of fewer materials	1		
Use of thermal mass		1	
Reuse or recycling of shelter materials after lifespan use		1	
ENERGY EFFICIENCY AND RENEWABLE ENERGIES			
Use of solar power		1	
Use of solar thermal energy(domestic hot water)		1	
Use of wind energy		1	
Use of other renewable energies		1	
TOTAL	**7**	**8**	**0**

On one hand, the wooden shelter case study applies with the use of local materials, the easy upgrading, and an environmental conscious way to build it with few sustainable materials. The use of timber coming from well managed forests is generally considered to have excellent environmental credentials. The shelter fails to incorporate re-used or recycled materials into the design. The shelter is intended to be demountable but the short lifespan of the untreated materials (with possible exception of the doors) mean that it is unlikely that they will be reused.

In the section of energy it doesn't incorporate any use of renewable energies.

According with the points obtained and the classification given in Table 3.2, the performance can be qualified as Adequate, AMBER. The shelter meets some of material use criteria but is expected to improve in other areas, with focus on the energy use.

4.3.4 Energy performance simulation and results

Physical properties of the envelope of the emergency shelter are as seen in Table 4.3.

Table 4.3: Physical properties of the envelope of wooden emergency shelter.

Element	Material	Thickness (mm)	Density (kg/m3)	U-value (W/m2K)
Structure	Timber	100	560	0.143
Walls	Plywood	12	560	0.143
Roof	Palm fiber	12	400	0.25
Floor	Palm fiber	12	400	0.25
Frames	Plywood	50	560	1.6
Openings	Glass	12	2579	4.6

The wooden emergency shelter is drawn as per the plans seen in Figure 4.16 and introduced in the program Design Builder to apply the physical properties listed in Table 4.3. In Figure 4.18 are seen the phases of the modeling.

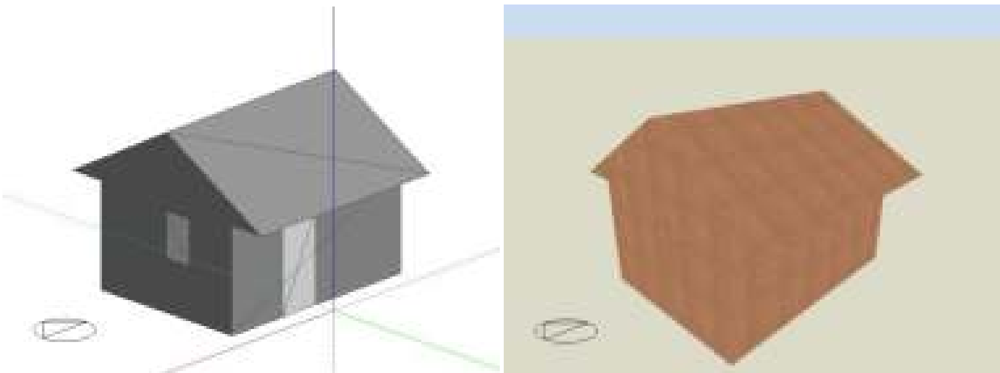

Figure 4.18: Wooden shelter geometry and model with materials applied.

Once the model is introduced in the program and the physical properties applied, the simulation proceeds in the five climatic zones of Turkey to obtain the factors of monthly temperatures, heat gains energy consumption as seen in the Figures 4.19 to 4.23.

– **Istanbul**

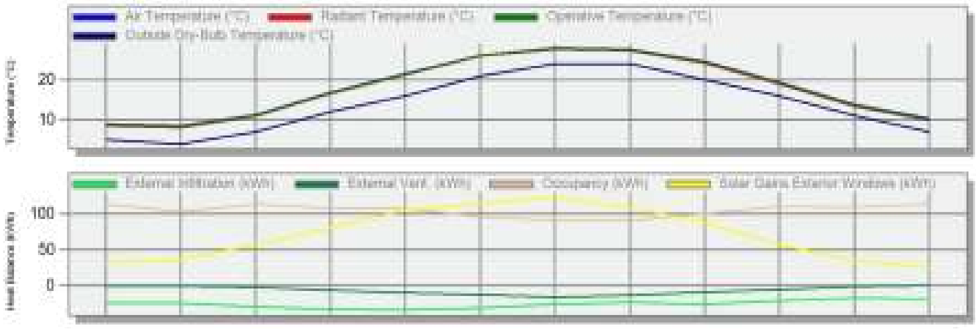

Figure 4.19: Istanbul. Monthly Operative Temperatures and Heat Gains. Wooden emergency shelter.

– **Ankara**

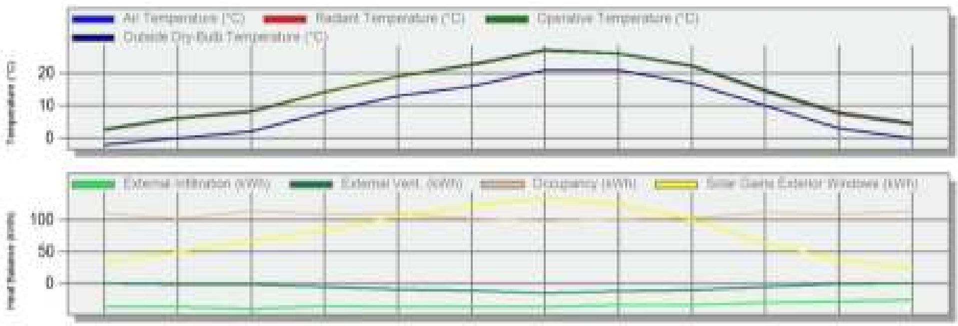

Figure 4.20: Ankara. Monthly Operative Temperatures and Heat Gains. Wooden emergency shelter.

– **Van**

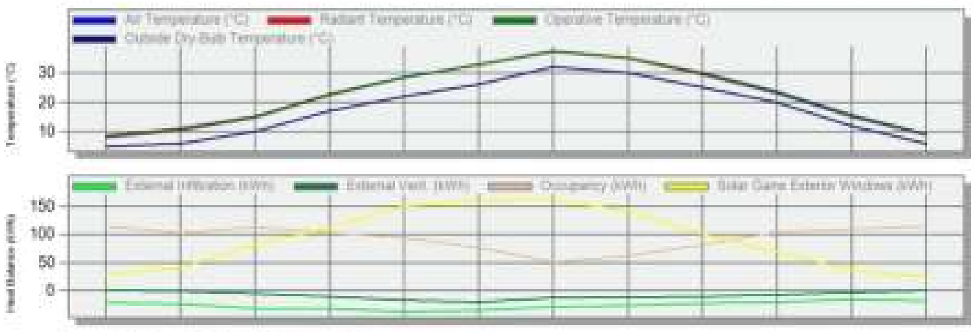

Figure 4.21: Van. Monthly Operative Temperatures, External infiltration and Heat Gains. Wooden emergency shelter.

– **Mugla**

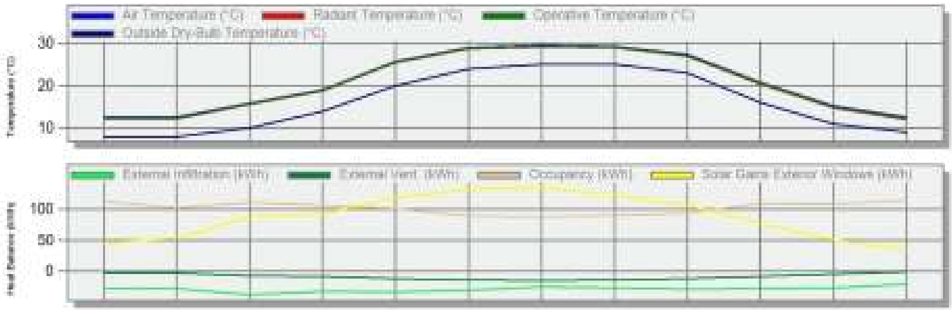

Figure 4.22: Mugla. Monthly Operative Temperatures and Heat Gains. Wooden emergency shelter.

– **Diyarbakir**

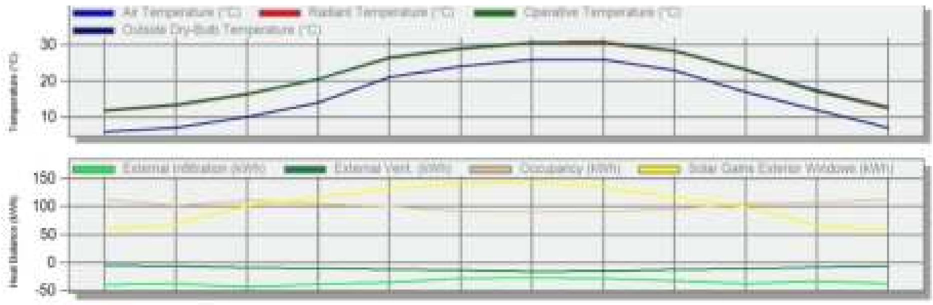

Figure 4.23: Diyarbakir. Monthly Operative Temperatures and Heat Gains. Wooden emergency shelter.

4.4 Evaluation of Plastic Emergency Shelter

In Tuesday 12, 2010 a catastrophic 7-magnitude earthquake struck near Port au Prince, Haiti. The initial earthquake was later followed by 12 aftershocks greater than magnitude 5.0. Structures of all kinds were damaged or collapsed. 220,000 people estimated to have died. Over 188.000 houses were badly damaged and 105.000 were destroyed by the earthquake (293.300 in total), 1.5 million people became homeless.[54]

At its peak, one and a half million people were living in displacement camps including over 100.000 at critical risk from storms and flooding.

The International Federation of Red Cross and Red Crescent introduced the construction of more than 5.000 temporary shelters.

4.4.1 Plastic emergency shelter description

The shelter is 3 x 6 m on plan (18m2) and has 6 columns spaced on a 3m grid, fixed to rectangular reinforced concrete foundations. The structure consists of a galvanized rectangular steel frame with an 8.5 degree mono-pitch roof and a suspended floor. Timber studs are screwed to the steel members and the plastic wall sheeting is attached to this. Additional timber sub-framing is used to form windows and doors.

The approximate material cost per shelter is $1800 and the approximate programme cost per shelter is $4500.[43]

The number built was 5100 with an anticipated lifespan of 24 months. The Figure 4.24 shows the emergency shelter on site and the earthquake location.

Figure 4.24: Plastic emergency shelter and earthquake location [45]

4.4.2 Plastic emergency shelter construction and materials

The shelter uses partly locally sourced materials and partly prefabricated. While the pre-fabricated steel frame solution is imported and relatively expensive, the plastic sheeting walls are easily available locally and cheap to acquire. The shelter can be quickly constructed in 2 days once the materials have arrived in-country.

The steel frame has very limited lateral stability because there is no bracing in the walls or roof. As such, it does not perform well under seismic and wind loading.

In Figure 4.25 are shown construction plan and section for the plastic emergency shelter.

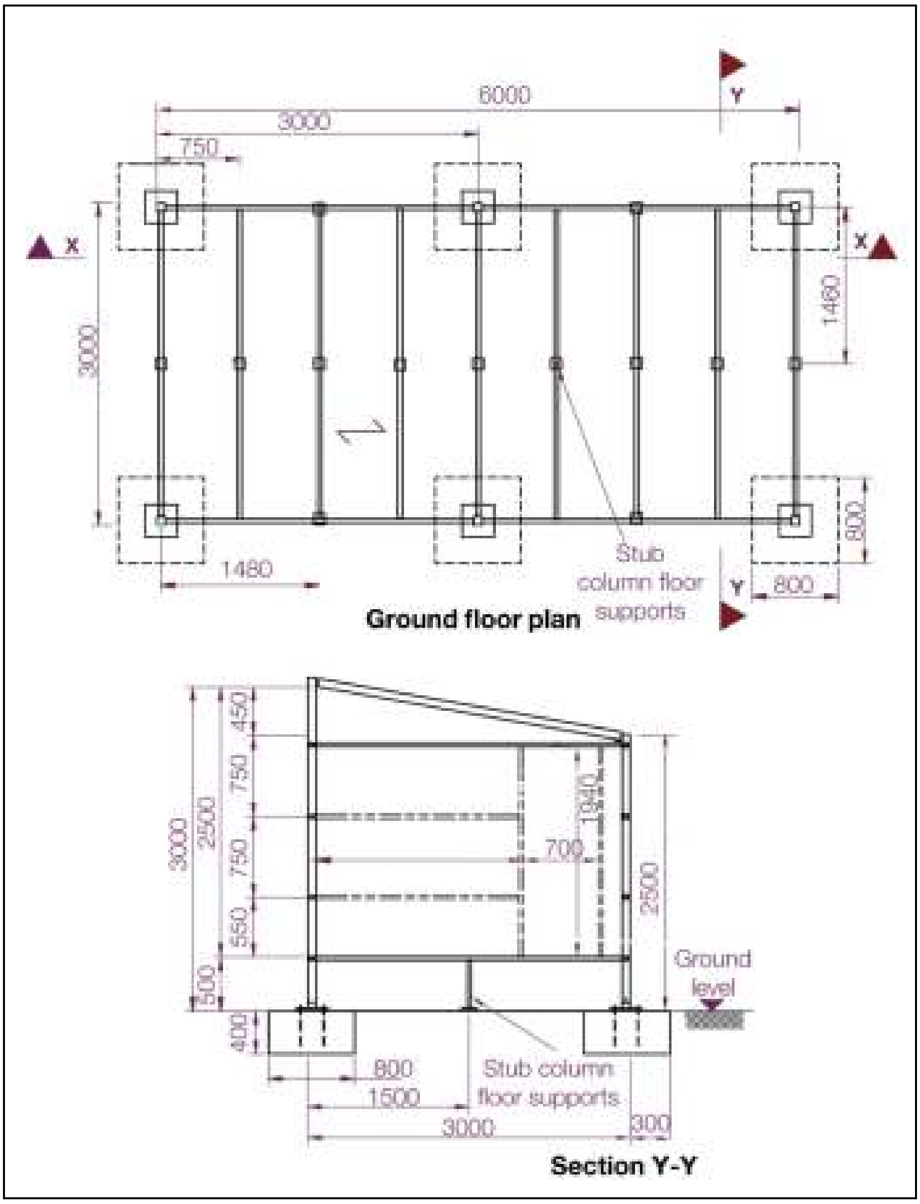

Figure 4.25: Plastic shelter plan and section [45]

4.4.3 Green evaluation checklist

Within the scope of this study, the evaluation using the approach of a green rating system focuses on the materials and energy efficiency and renewable sections. The section of site selection is not included as the emergency shelters selected are abstracted to be in the five climate regions of Turkey in a simulated site. The sections of water efficiency and indoor environment are not included for the lack of verifiable information.

In the following Table 4.4 it is shown the green checklist results for this emergency shelter.

Table 4.4: Plastic emergency shelter green rating.

MATERIALS	YES	NO	No information
Use of local materials		1	
Easy maintenance and upgrade of materials	1		
Reuse of materials	1		
Use of recycled materials		1	
Use of earth materials and low embodied energy materials		1	
Use of non toxical&non contamining materials			1
Use of low impact construction methods	1		
Support of sustainable and legal sourcing materials			1
Use of fewer materials		1	
Use of thermal mass		1	
Reuse or recycling of shelter materials after lifespan use	1		
ENERGY EFFICIENCY AND RENEWABLE ENERGIES			
Use of solar power		1	
Use of solar thermal energy(domestic hot water)		1	
Use of wind energy		1	
Use of other renewable energies		1	
TOTAL	**4**	**9**	**2**

The plastic shelter both uses local and imported materials. While the shelter is demountable with foundation bolts that can be cut to reuse the frame, the plastic sheeting will require replacement. So in the materials field the emergency shelter presents a polarized performance, while applies with some strategies with local materials also uses pre-fabricated ones that have to be imported from outside. The use of plastic implies a high embodied energy.

The anticipated lifespan of 24 months would make it reasonable to incorporate sustainable energy efficient strategies to the shelter but despite of this fact none of them are designed nor incorporated to the construction.

According with the points obtained and the classification given in Table 3.2, the performance can be qualified as Deficient, RED. The shelter is expected to improve in most of the areas for sustainability, with special focus on the use of local materials and the incorporation of energy efficient measures.

4.4.4 Energy performance simulation and results

Physical properties of the envelope of the emergency shelter are as seen in Table 4.5

Table 4.5: Physical properties of the envelope of plastic emergency shelter.

Element	Material	Thickness (mm)	Density (kg/m3)	U-value (W/m2K)
Structure	Steel	100	7700	2.2
Walls	Polyethylene	0.5	0.925	1.2
Roof	Steel	0.5	400	0.25
Floor	Plywood	12	400	0.25
Frames	Plywood	50	560	1.6
Openings	Glass	12	2579	4.6

The plastic emergency shelter is drawn as per the plans seen in Figure 4.25 and introduced in the program Design Builder to apply the physical properties listed in Table 4.5. In Figure 4.26 are shown the phases of the modeling.

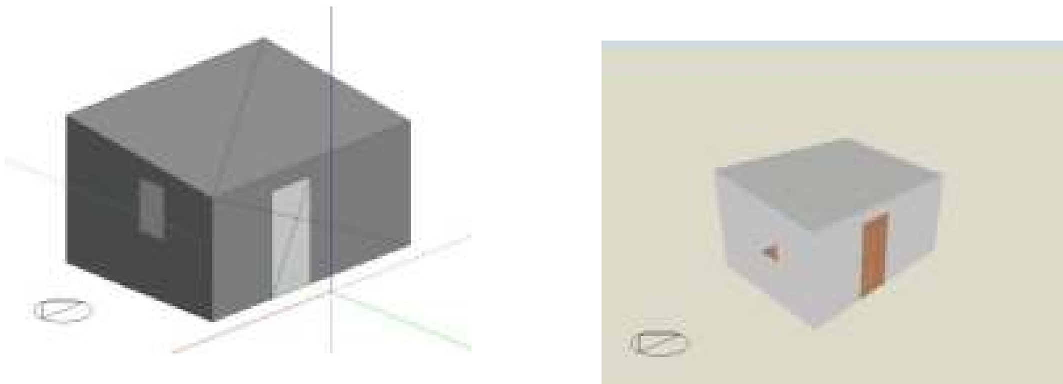

Figure 4.26: Plastic emergency shelter geometry and model with materials applied.

Once the model is introduced in the program and the physical properties applied, the simulation proceeds in the five climatic zones of Turkey to obtain the factors of monthly temperatures, heat gains energy consumption as seen in the Figures 4.27 to 4.31.

- **Istanbul**

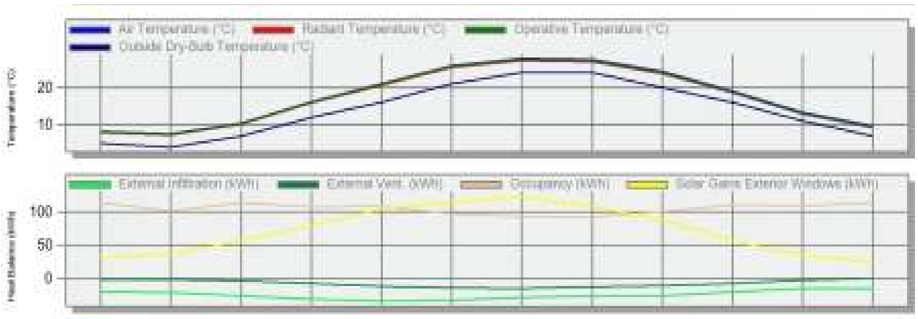

Figure 4.27: Istanbul. Monthly Operative Temperatures and Heat Gains. Plastic emergency shelter.

- **Ankara**

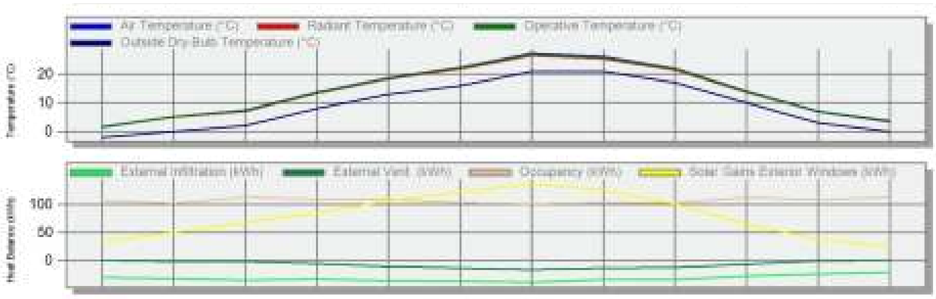

Figure 4.28: Ankara. Monthly Operative Temperatures and Heat Gains. Plastic emergency shelter.

- **Van**

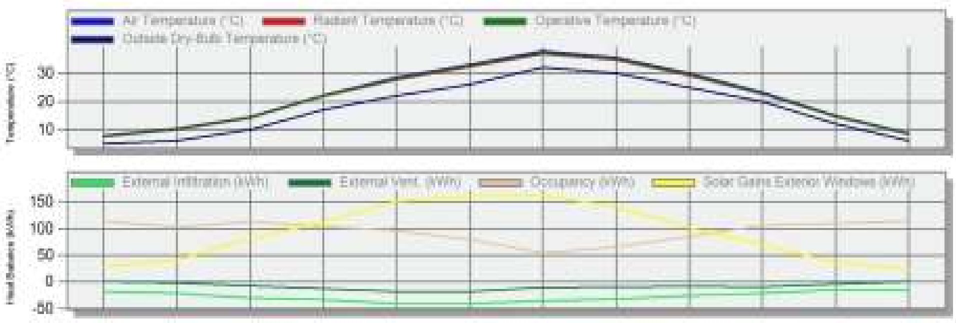

Figure 4.29: Van. Monthly Operative Temperatures and Heat Gains. Plastic emergency shelter.

– **Mugla**

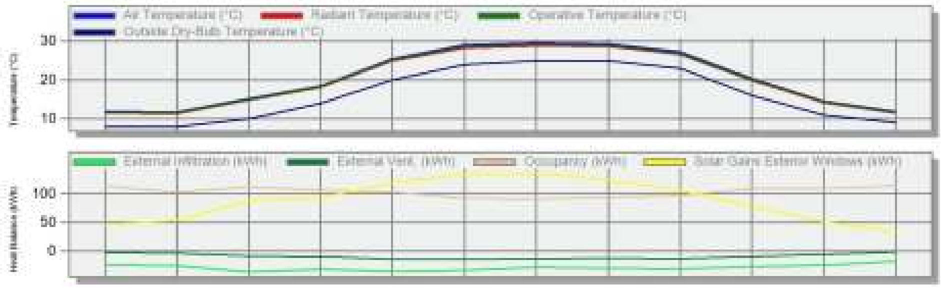

Figure 4.30: Mugla. Monthly Operative Temperatures, External infiltration and Heat Gains. Plastic emergency shelter.

– **Diyarbakir**

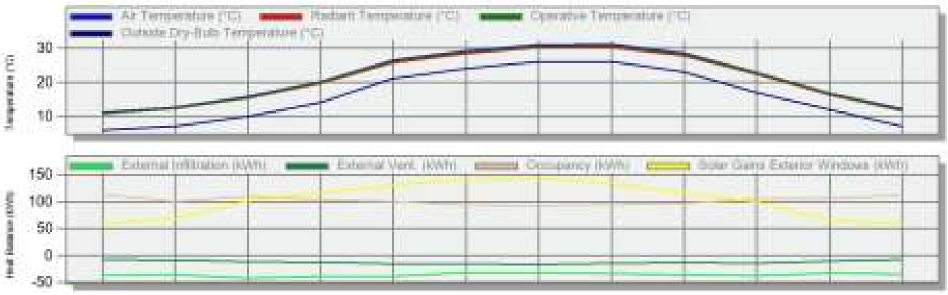

Figure 4.31: Diyarbakir. Monthly Operative Temperatures and Heat Gains. Plastic emergency shelter.

4.5 Evaluation of Metal Emergency Shelter

In October 23, 2011 a destructive magnitude 7.1 earthquake struck about 16 kilometers north-northeast of Van, Turkey. Due to its great intensity and shallow depth, the earthquake produced significant ground motions across a large area. The earthquake killed more than 600 people and injured more than 4.000. More than 11.000 buildings sustained damage in the region, 6.000 of which were found to be uninhabitable.

Two post-disaster housing cities were established in Van and in Erciş with 518 shelters set in the latter and providing shelter for 1.064 beneficiaries (266 families). In addition, 2.208 were also delivered to the affected areas and were used for settlements and for individual needs (552 families).

4.5.1 Metal emergency shelter description

The shelter is called Mevlana house and it's a prefabricated shelter with a 18 m2 area of use and made of reinforced aluminum profile frame and walls and roof from polyurethane filled metal panels.[55]

Each house can accommodate 4/5 persons. No foundation is required and neither is any structural assembly. These panels are capable of flexing (during an earthquake), and they have enough spine to return to its original position when the shaking stop so is very earthquake adequate. They are suitable for winter conditions due to their polyurethane thermal insulation. The wiring system helps beneficiaries to use electricity. The AC electrical system includes breaker panel, six fluorescent light fixtures, wall receptacles and wiring. Within 5 minutes, the installation of the house can be completed.

The price of each basic prefabricated mevlana house is $5800 and $6600 furnished.[55]

The number built was 2.300 with an anticipated lifespan of 12 months. Figure 4.32 shows the emergency shelter assembled and the earthquake location.

Figure 4.32: Metal emergency shelter and earthquake location [45]

4.5.2 Metal emergency shelter construction and materials

The emergency shelter is built of steel in accordance with international standards and assembled without welding so it can be modified and easily dismantled. Sandwich panels are assembled in roof and walls have excellent insulating characteristics thanks to the integration of insulating material. Sandwich panels consist of two steel cover sheets, which are shear-resistant and are bonded to one another on an insulated core of polyurethane. Sandwich panels are produced by continuously running production plants and sawn to ordered lengths.

The emergency shelter has also an adequate sanitation: wall-mounted wash basin, toilet and reservoir, acrylic shower tray (80x80 cm).

In the following Figure 4.33 are shown construction plan and section.

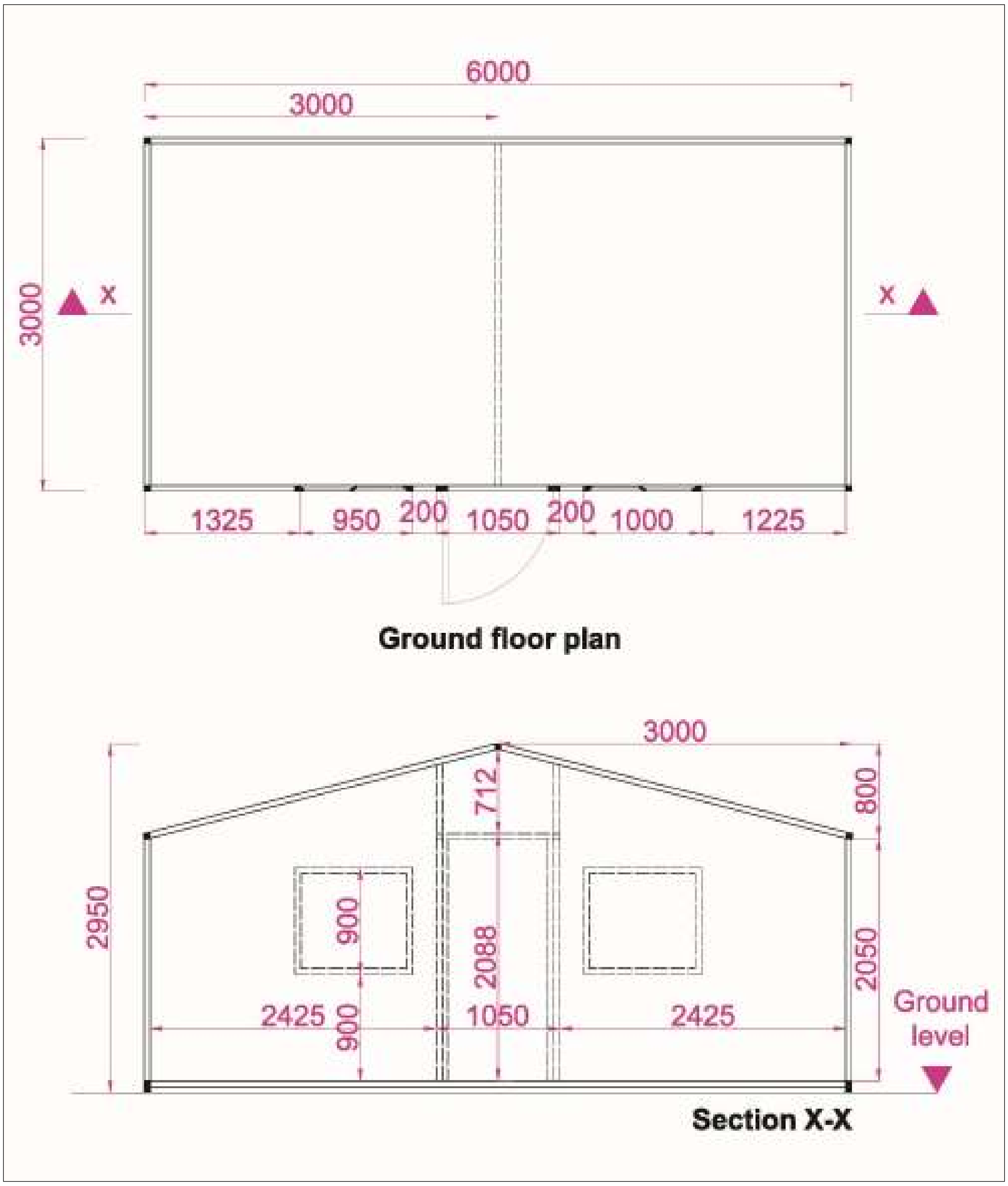

Figure 4.33: Metal shelter plan and section[45]

4.5.3 Green evaluation checklist

Within the scope of this study, the evaluation using the approach of a green rating system focuses on the materials and energy efficiency and renewable sections. The section of site selection is not included as the emergency shelters selected are abstracted to be in the five climate regions of Turkey in a simulated site. The sections of water efficiency and indoor environment are not included for the lack of verifiable information.

In the following Table 4.6 it is shown the green checklist results for this emergency shelter.

Table 4.6: Metal emergency shelter green rating.

MATERIALS	YES	NO	No information
Use of local materials		1	
Easy maintenance and upgrade of materials	1		
Reuse of materials		1	
Use of recycled materials		1	
Use of earth materials and low embodied energy materials		1	
Use of non toxical&non contamining materials			1
Use of low impact construction methods	1		
Support of sustainable and legal sourcing materials			1
Use of fewer materials	1		
Use of thermal mass		1	
Reuse or recycling of shelter materials after lifespan use	1		
ENERGY EFFICIENCY AND RENEWABLE ENERGIES			
Use of solar power		1	
Use of solar thermal energy(domestic hot water)		1	
Use of wind energy		1	
Use of other renewable energies(geothermal,biomas..)		1	
TOTAL	**4**	**9**	**2**

The metal shelter uses a prefabricated system that while fast to mount and easy to maintain, uses non-local materials and doesn't attempt to incorporate reuse or recycling in its design process. Also involves importation from abroad, adding carbon footprint. Metals have a high embodied energy and the use of prefabricated construction uses an extensive processing of materials that inevitably requires the use of energy and results in waste generation.

In the same line, the emergency shelter loses the opportunity to incorporate in the design phase a pre-fabricated system such as photovoltaic roof, rain water re-use, etc to improve sustainability.

According with the points obtained and the classification given in Table 3.2, the performance can be qualified as Deficient, RED. This post-disaster housing is expected to improve in most of the areas for energy efficiency and sustainability criteria.

4.5.4 Energy performance simulation and results

Physical properties of the envelope of the emergency shelter are as seen in Table 4.7.

Table 4.7: Physical properties of the envelope of metal emergency shelter.

Element	Material	Thickness (mm)	Density (kg/m3)	U-value (W/m2K)
Structure	Steel	100	7700	2.2
Walls	Sand.panel	50	24	0.44
Roof	Sand.panel	50	400	0.44
Floor	Plywood	12	400	0.25
Frames	Aluminium	50	2800	3.8
Openings	Glass	12	2579	4.6

The metal emergency shelter is drawn as per the plans seen in Figure 4.33 and introduced in the program Design Builder to apply the physical properties listed in Table 4.7. In Figure 4.34 are shown the phases of the modeling.

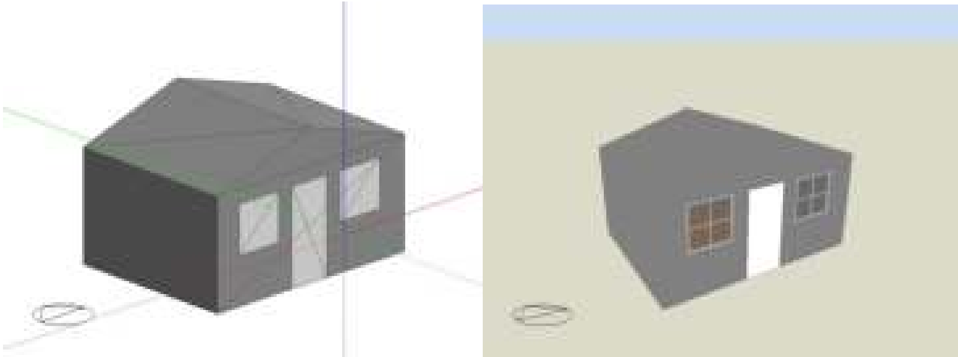

Figure 4.34: Plastic emergency shelter geometry and model

Once the model is introduced in the program and the physical properties applied, the simulation proceeds in the five climatic zones of Turkey to obtain the factors of monthly temperatures, heat gains energy consumption as seen in the figures 4.35 to 4.39.

- **Istanbul**

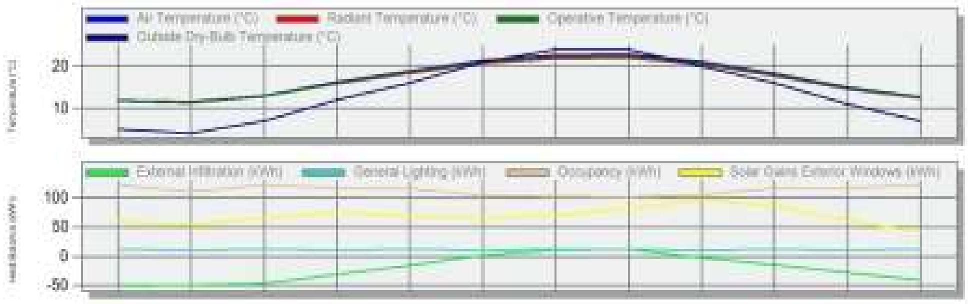

Figure 4.35: Istanbul. Monthly Operative Temperatures and Heat Gains. Metal emergency shelter.

- **Ankara**

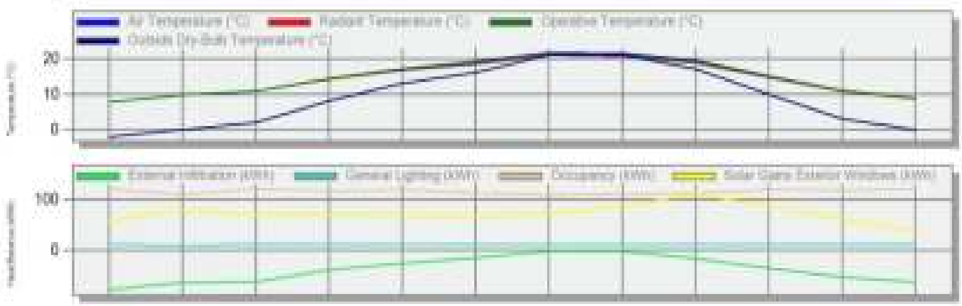

Figure 4.36: Ankara. Monthly Operative Temperatures and Heat Gains. Metal emergency shelter.

– **Van**

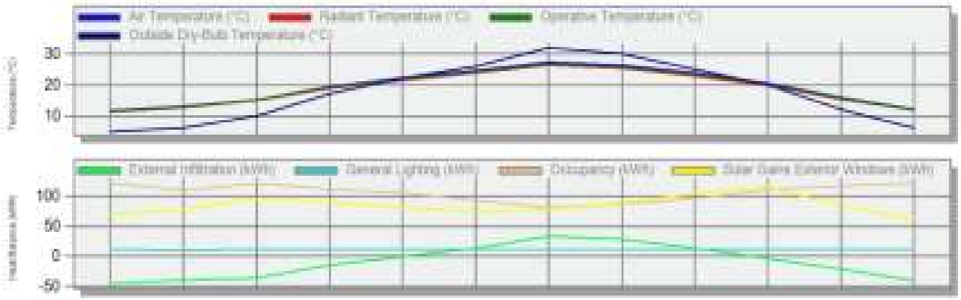

Figure 4.37: Van. Monthly Operative Temperatures and Heat Gains. Metal emergency shelter.

– **Mugla**

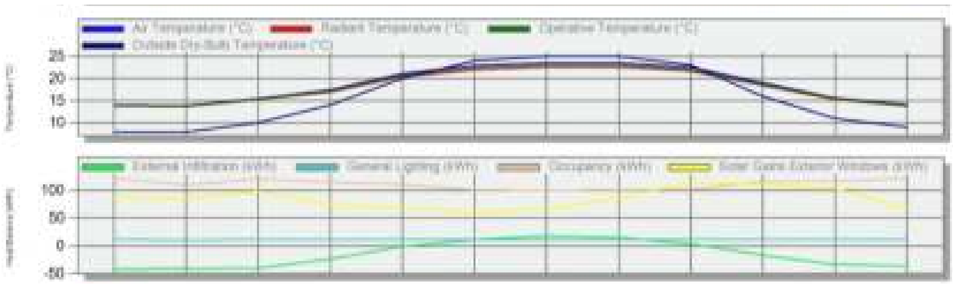

Figure 4.38: Mugla. Monthly Operative Temperatures and Heat Gains. Metal emergency shelter.

– **Diyarbakir**

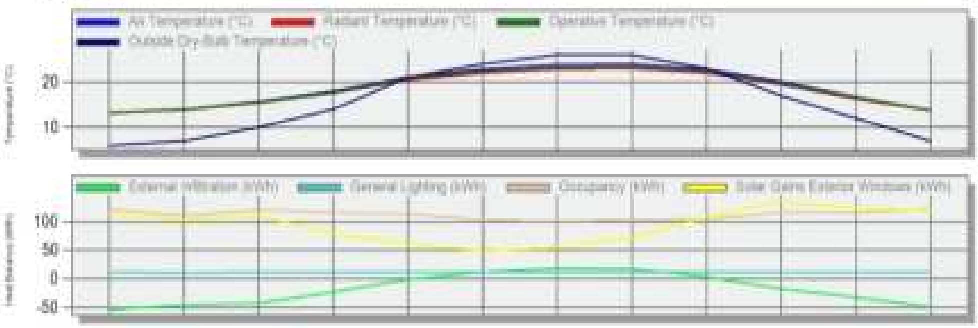

Figure 4.39: Diyarbakir. Monthly Operative Temperatures and Heat Gains. Metal emergency shelter.

5. COMPARISON AND EVALUATION OF CASE STUDY EMERGENCY SHELTERS

This chapter is divided in 3 parts. In the first section, the individual results for each shelter according to the approach to a new green rating system are compared. Conclusions about the sustainable performance of the case studies are achieved.

In the second section, the operative temperature results of each emergency shelter, calculated in the previous chapter, are compared. This comparation obtains a wider understanding of the thermal comfort of the case studies when they are used under natural conditions, without the intervention of mechanical systems for indoor comfort.

In the third and last section, the three emergency shelters are simulated with mechanical systems for indoor thermal comfort. This simulation allows the comparison of the energy consumption for each shelter under the different climatic conditions. This comparison shows the diverse energy performance of each shelter and brings conclusions of the suitability of these designs under a range of different climatic conditions.

5.1 Green Evaluation Checklist Comparison

In the previous chapter each emergency shelter was analyzed individually under the criteria of the green rating system focused on emergency architecture. In the following Table 5.1 below there is a comparative table between the three case studies focused on the materials and energy efficiency and renewable energies criterias.

Table 5.1: Comparison of green rating system for 3 case studies.

	Wooden shelter			Plastic shelter			Metal shelter		
MATERIALS	YES	NO	No info	YES	NO	No info	YES	NO	No info
Use of local materials	1				1			1	
Easy maintenance and upgrade of materials	1			1			1		
Reuse of materials		1		1				1	
Use of recycled materials		1			1			1	
Use of earth materials and low embodied energy materials	1				1			1	
Use of non toxical&non contamining materials	1					1			1
Use of low impact construction methods	1			1			1		
Support of sustainable and legal sourcing materials	1					1			1
Use of fewer materials	1				1		1		
Use of thermal mass		1			1			1	
Reuse or recycling of shelter materials after lifespan use		1		1			1		
ENERGY EFFICIENCY AND RENEWABLE ENERGIES									
Use of solar power		1			1			1	
Use of solar thermal energy(domestic hot water)		1			1			1	
Use of wind energy		1			1			1	
Use of other renewable energies(geothermal,biomas..)		1			1			1	
TOTAL	7	8	0	4	9	2	4	9	2

From the table above several facts can be concluded:

- The three shelters have a similar use of materials regarding a tendency to use fewer materials, whole or partially local sources, easy maintenance or upgrade and low impact of their construction methods.
- The weakness on the field of materials used comes from a tendency to not incorporating recycling or re-use techniques.
- In the field of the use of renewable energies the three case studies fail to incorporate in their design techniques on this direction to make them more sustainable.

5.2 Operative Temperature Comparison

From Figure 5.1 to 5.5. there is a comparative table between the three case studies for each of the 5 climatic zones

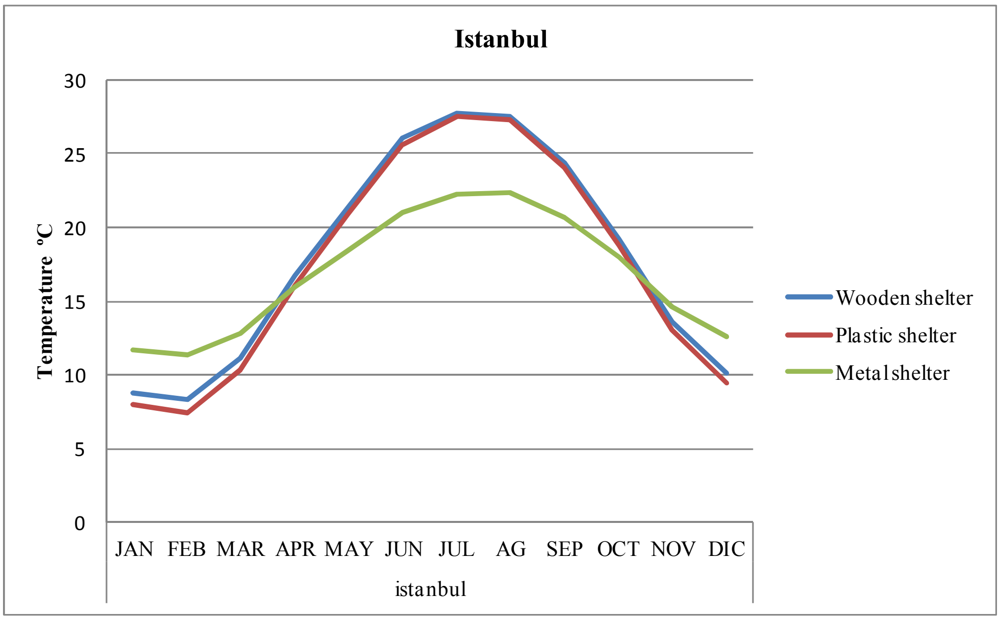

Figure 5.1: Emergency shelters operative temperatures comparison. Istanbul.

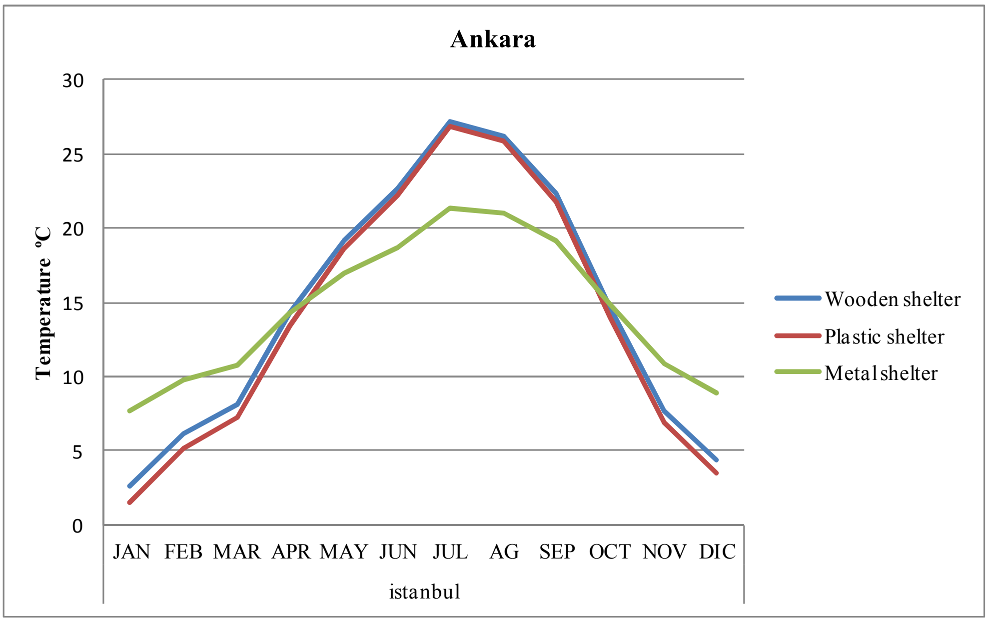

Figure 5.2: Emergency shelters operative temperatures comparison. Ankara.

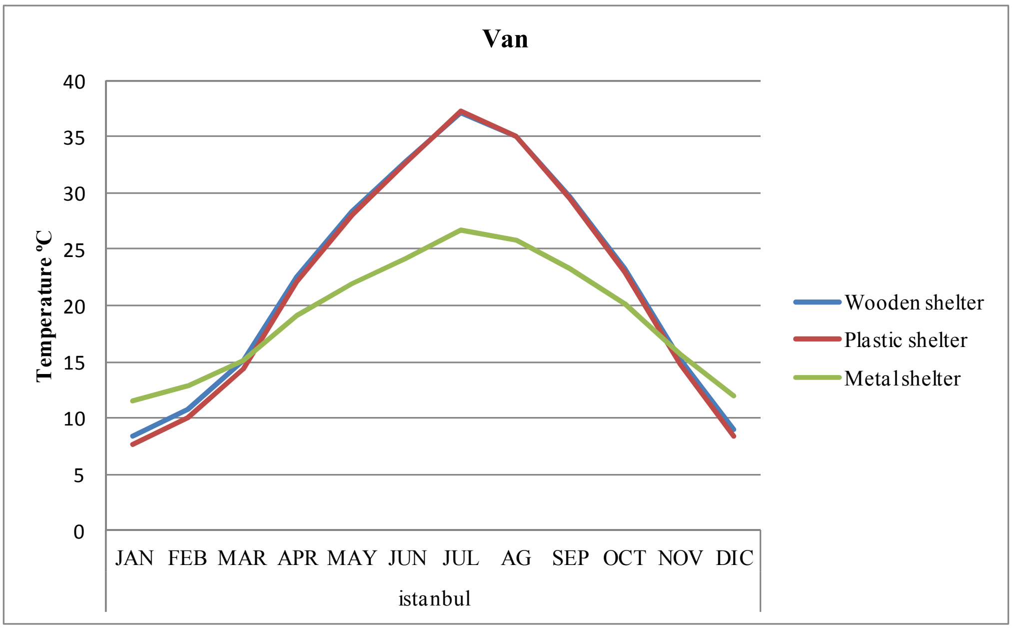

Figure 5.3: Emergency shelters operative temperatures comparison. Van.

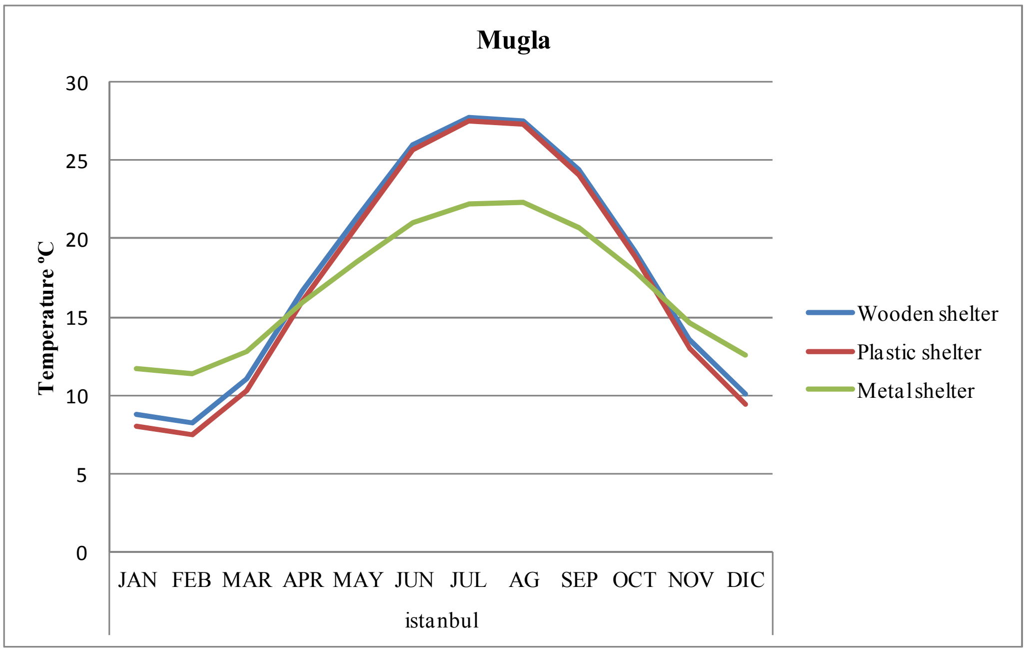

Figure 5.4: Emergency shelters operative temperatures comparison. Mugla.

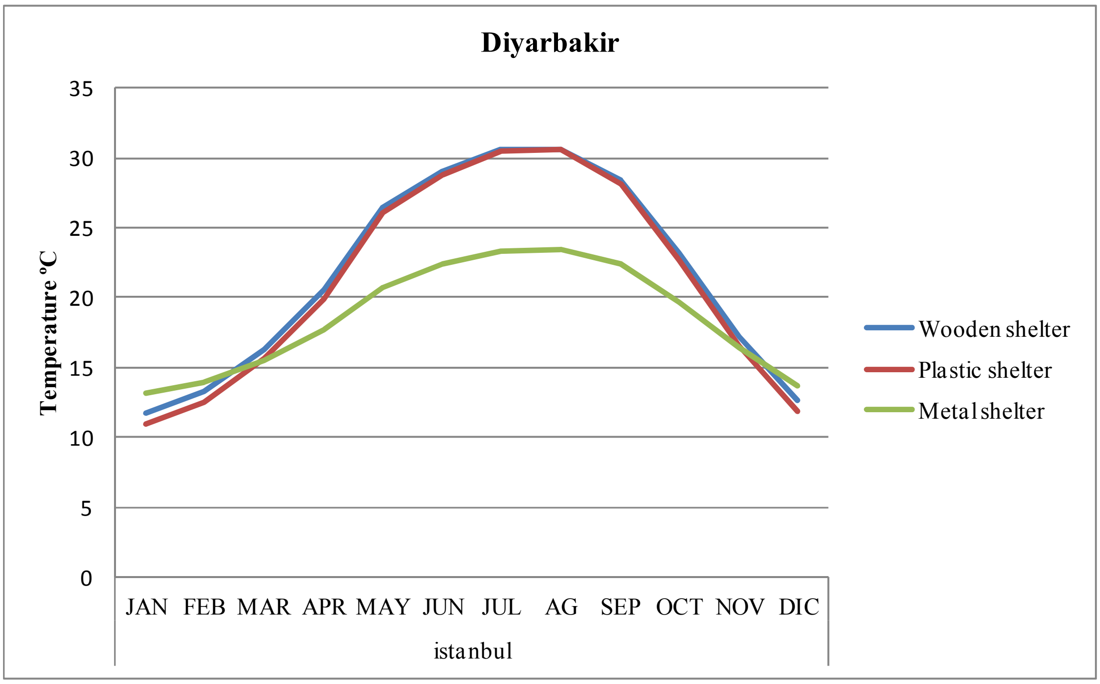

Figure 5.5: Emergency shelters operative temperatures comparison. Diyarbakir.

Below, the Figure 5.6, shows the comparison for the 3 case studies in the five climatic zones of Turkey. In blue, the wooden shelter; in red, the plastic shelter and in green, the metal shelter.

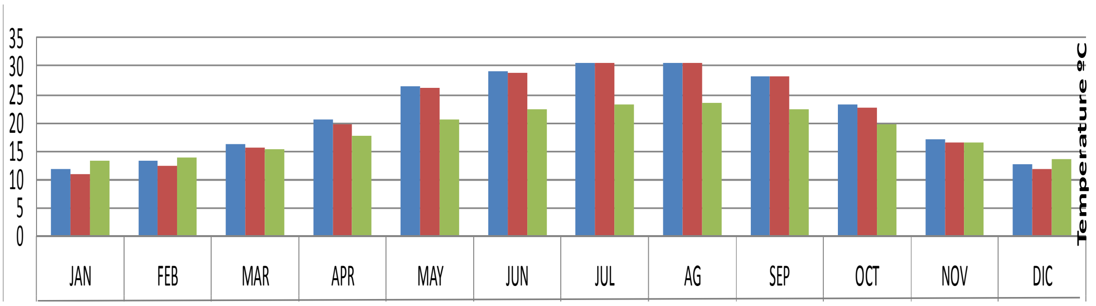

Figure 5.6: Emergency shelters operative temperatures comparison

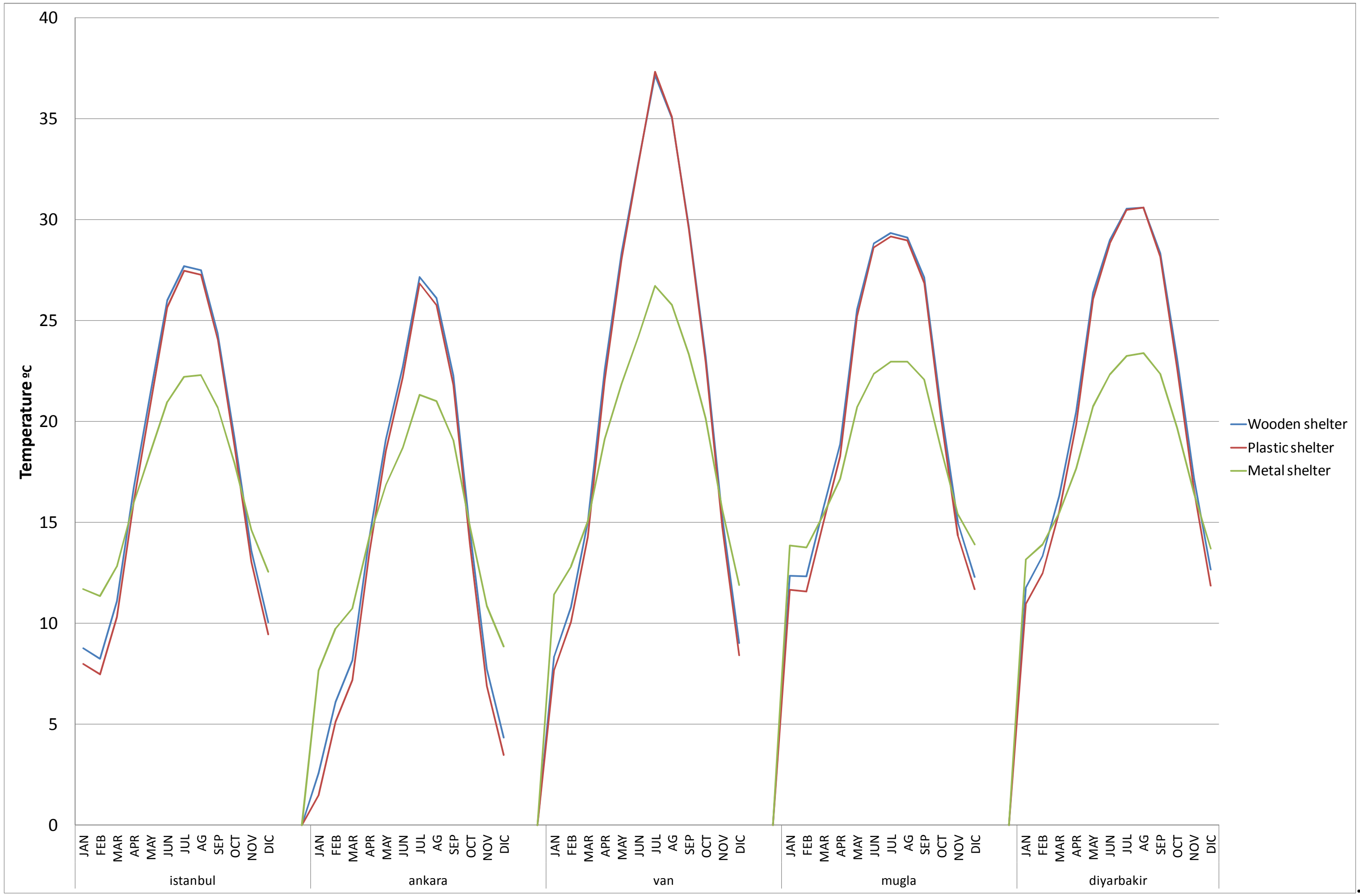

Figure 5.7: Summary graph of operative temperature for 3 emergency shelters in five climatic zones of Turkey

From the results of the operative temperatures shown from Figures 5.1 to 5.5 and the Figure 5.6, that shows the annual average comparison for the 3 case study in the five climatic zones, it can be inferred that:

– The results of this simulations shows that the temperature performance for the wooden and plastic shelter are almost identical for all the climates.

– The metal emergency shelter shows a more balanced performance, without extreme temperatures for the winter and summer months. This is due to the insulation of the sandwich panels and the use of lighting system that provides certain heating.

Below, in the Figure 5.8, there is a comparative table between the three case studies for each of the 5 climatic zones according to their maximum and minimum operative temperatures as well as the comfort temperature zone.

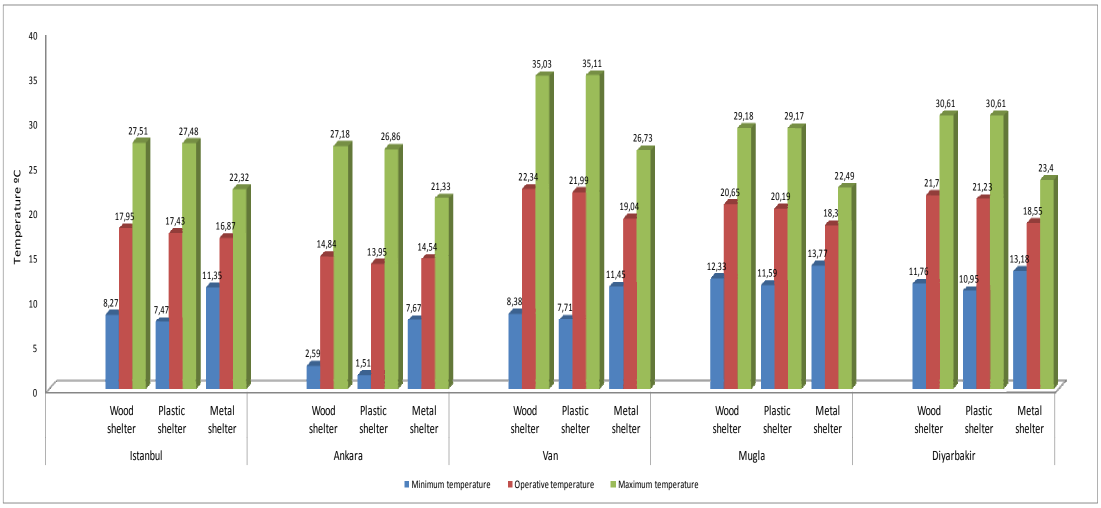

Figure 5.8: Max/min operative temperature for the 3 emergency shelters in the five climatic zones.

In this figure we can see the comparison of the year maximum (green) and minimum (blue) operative temperature as well as the average operative temperature (red) for the three typologies of shelters(wooden, plastic and metal) in the five climatic areas(Istanbul, Ankara, Van, Mugla and Diyarbakir). We can observe as well the comfort temperature in doted blue lines (between 21-24ºC)

For Istanbul and Ankara climates it can be observed that the average operative temperature is below the comfort temperature and just reached by the metal shelter in the summer season.

For Van, Mugla and Dyarbakir the comfort temperature is reached but, especially in the case of Van, the maximum temperatures during the hot season is excessive for the occupants of the shelters, reaching the 35ºC in the case of Van.

The results show that unconditioned shelters can have an adequate performance for the climatic zones of Turkey. Still some design considerations must be made according to the climate they are placed:

- Warm-humid climate: Direct solar gain should be minimised particularly during the hottest period of the day through the use of shading techniques. Lightweight walls are preferable, minimising the thermal mass of the shelter. Materials that allow ventilation (like timber planks) should be selected. Elevating shelters may encourage air flow. Prevailing wind direction should be considered to maximise the potential for cross ventilation.
- Hot-dry climate: Vegetation may be used to minimise the heat gain of walls during the hottest part of the day and also create a more comfortable microclimate. Radiant heat gain can be minimised through double-skin techniques, encouraging ventilation through the roof. Insulation materials such as thatch, straw, mud, timber panels or fibre board, can be used to maintain differences in temperature between internal and external conditions.
- Cold climate: High thermal mass and/or substantial insulation are important for maintaining suitable temperatures, and to reduce the emergency shelter's energy demand. Plastic sheeting can be used to limit the infiltration of cold air. Insulation can also be used to sub-divide the indoor space and create thermal buffer zones, such as a vestibule in front of the door. A compact form is functional to reduce heat loss in cold climates. Ventilation should be minimised as air entering the shelter from outside will act to cool the internal space.

When these results are crossed with the green checklist results we can have a complete understanding of the energy performance and the sustainable behavior of each of the emergency shelter.

5.3 Energy Consumption Comparison

In the previous section, the emergency shelter are simulated in the different climatic zones of Turkey to obtain their operative temperatures and compare their performance under real unconditioned situation.

To achieve a full understanding of the energy performance of the case study emergency shelters, these are simulated under conditions where energy is required to provide indoor comfort. The assumptions made for these simulations are as it follows:

– The emergency shelters are simulated with a generic fan-coil. A fan coil unit (FCU) is a simple device consisting of a heating or cooling coil and fan. The fan coil unit may be wall mounted, freestanding or ceiling mounted, with return air grille and supply air diffuser set into that enclosure to distribute the air.

– The heating energy consumption is the one required to reach the Zone Sensible Heating, that is the overall sensible heating effect of any air introduced into the zone through the HVAC system. It is best thought of as the overall HVAC heating contribution to the zone heat balance.

– The five climatic zones and conditions have the same characteristics as previously detailed in section 4.1.

From Figures 5.9 to 5.12 it is shown the graphics with the monthly heating energy consumption in KWh from the three case study shelters in the five different climatic zone of Turkey. In blue, the wooden shelter; in red, the plastic shelter and in green, the metal shelter.

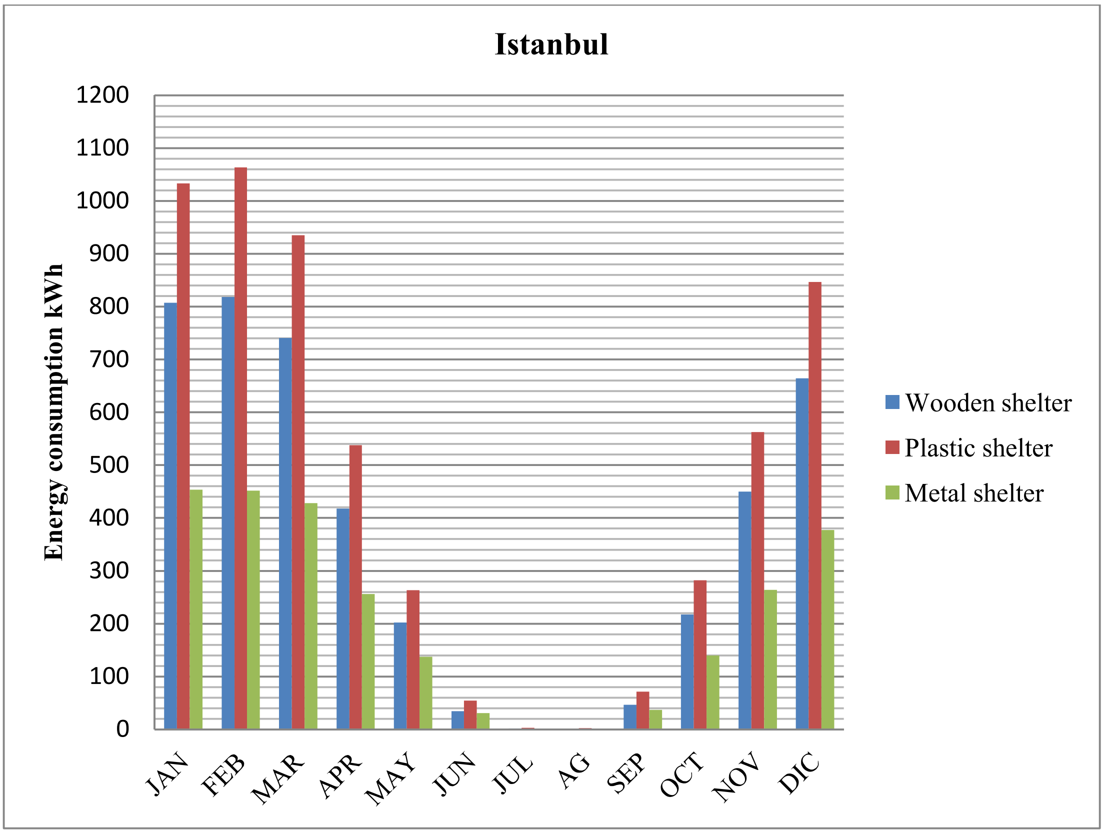

Figure 5.9: Heating energy consumption for the case emergency shelters in Istanbul.

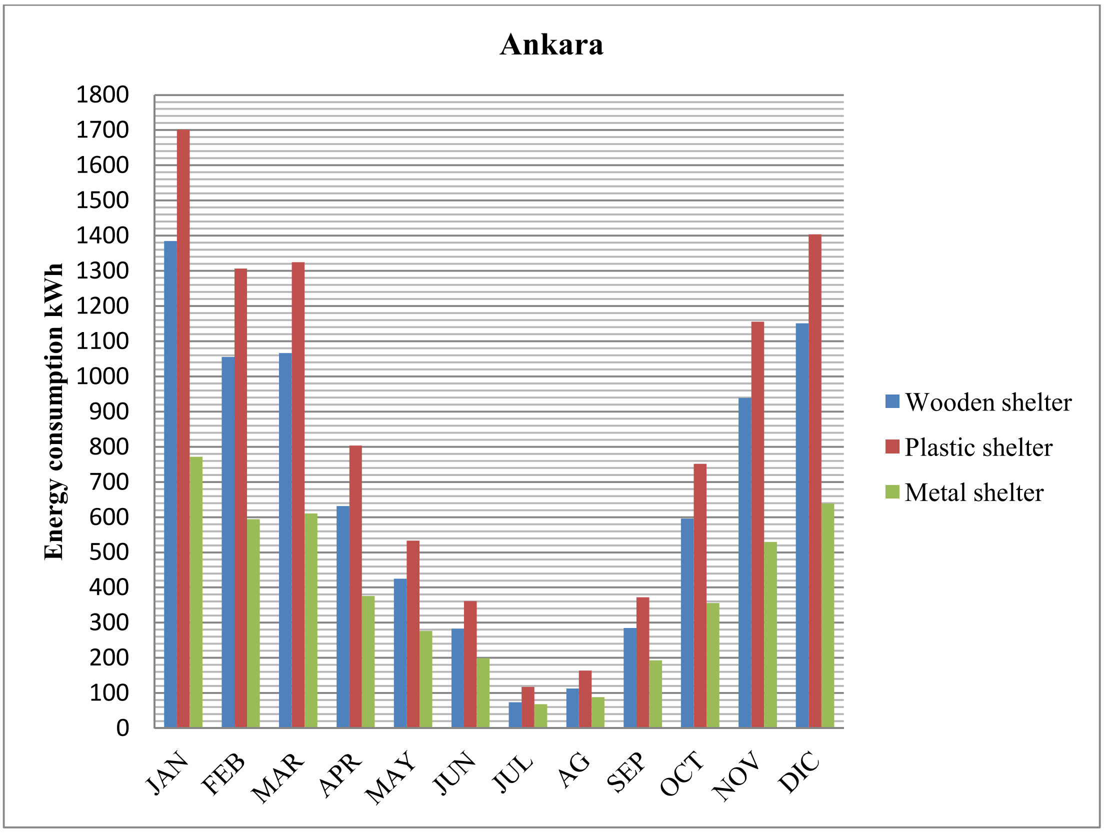

Figure 5.10: Heating energy consumption for the 3 emergency shelters in Ankara.

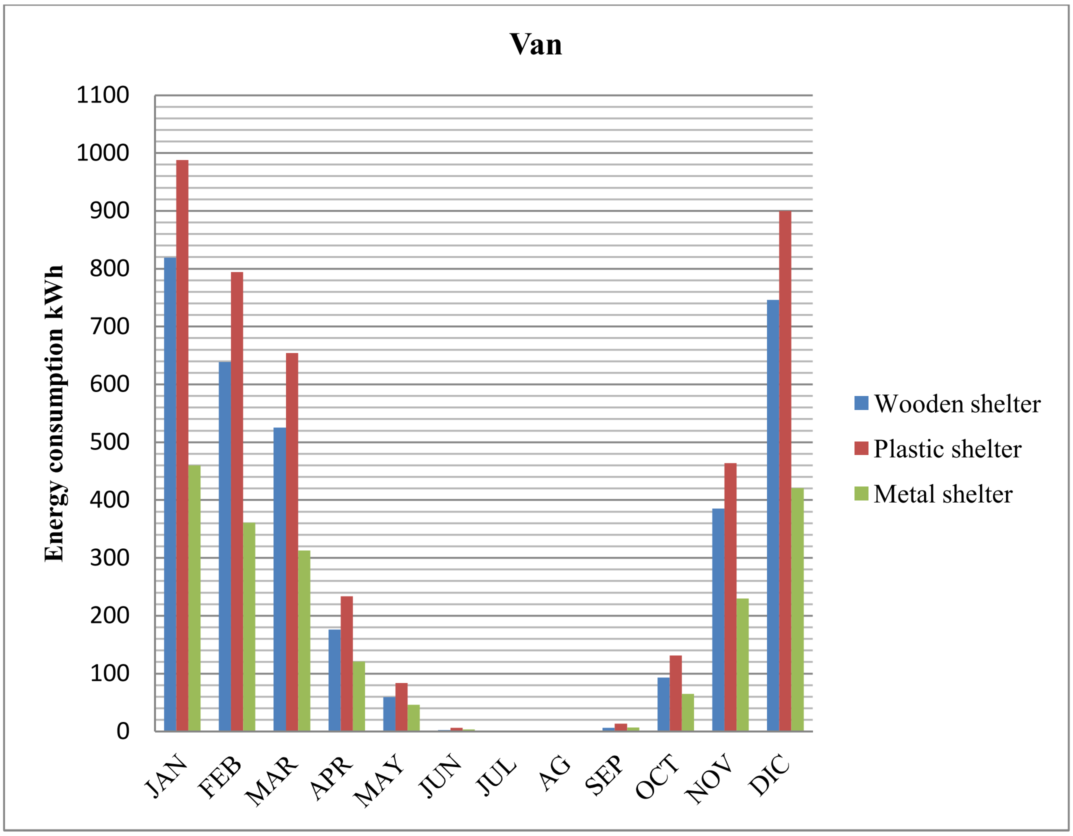

Figure 5.11: Heating energy consumption for the case emergency shelters in Van.

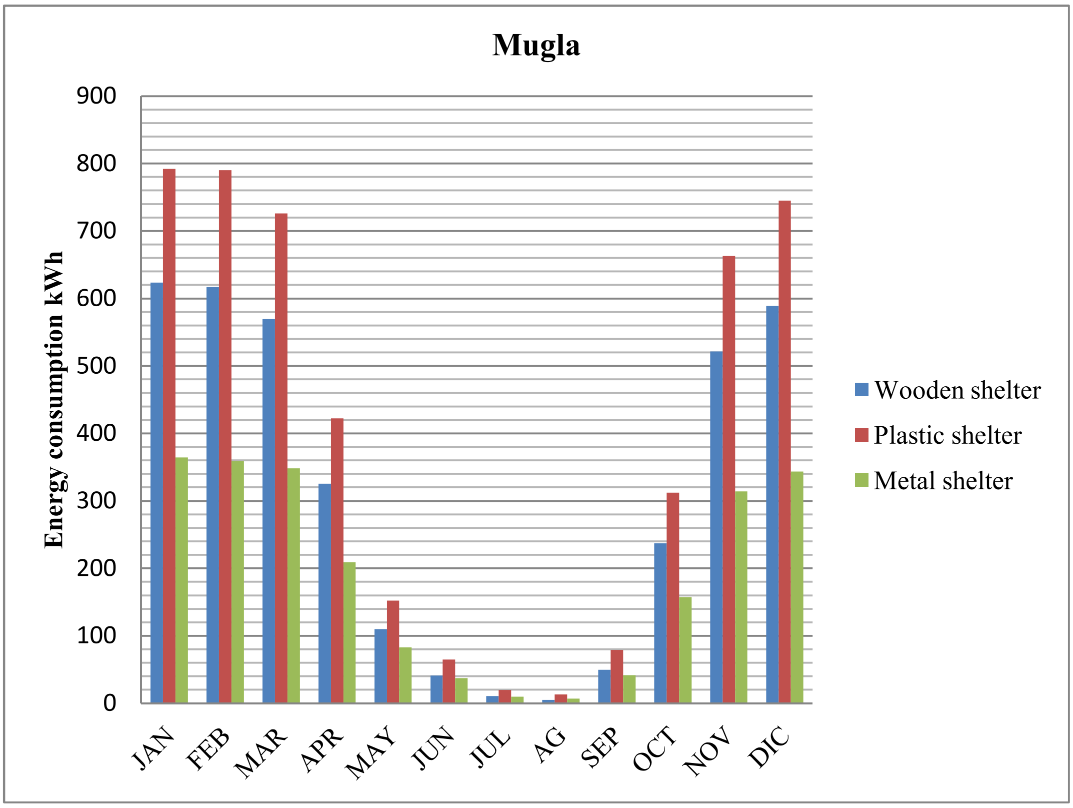

Figure 5.12: Heating energy consumption for the case emergency shelters in Mugla.

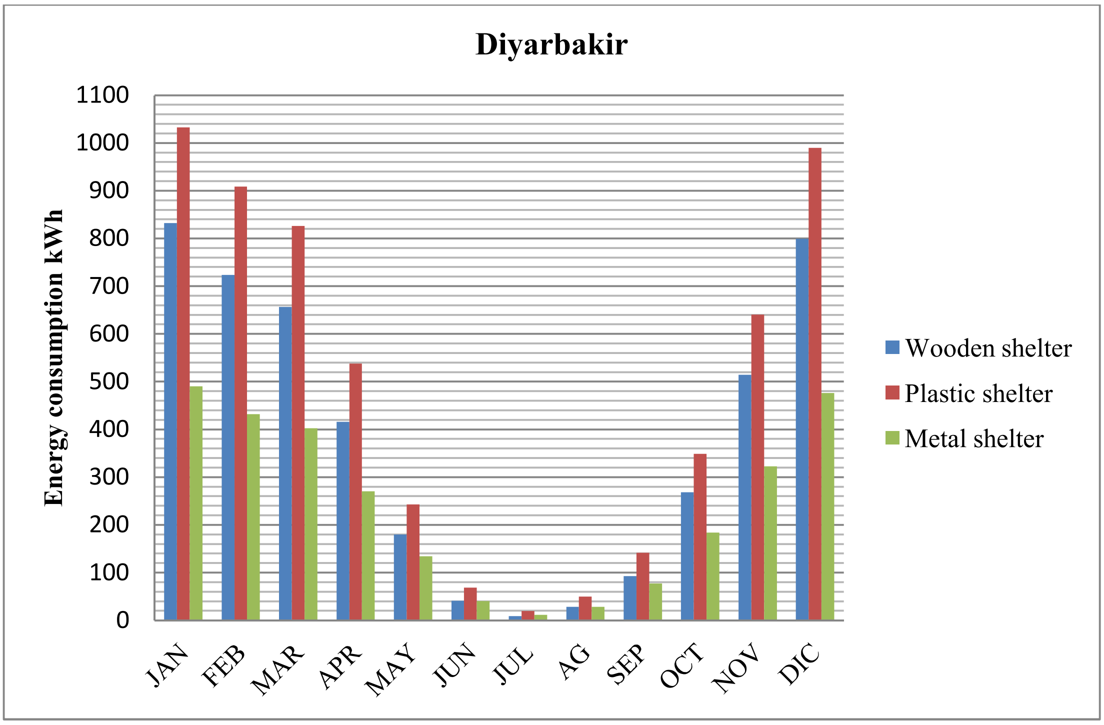

Figure 5.13: Heating energy consumption for the case emergency shelters in Diyarbakir

Below, the Figure 5.14, shows the comparison for the 3 case studies in the five climatic zones of Turkey. In Figure 5.15 it s shown a graph summary of the case studies.

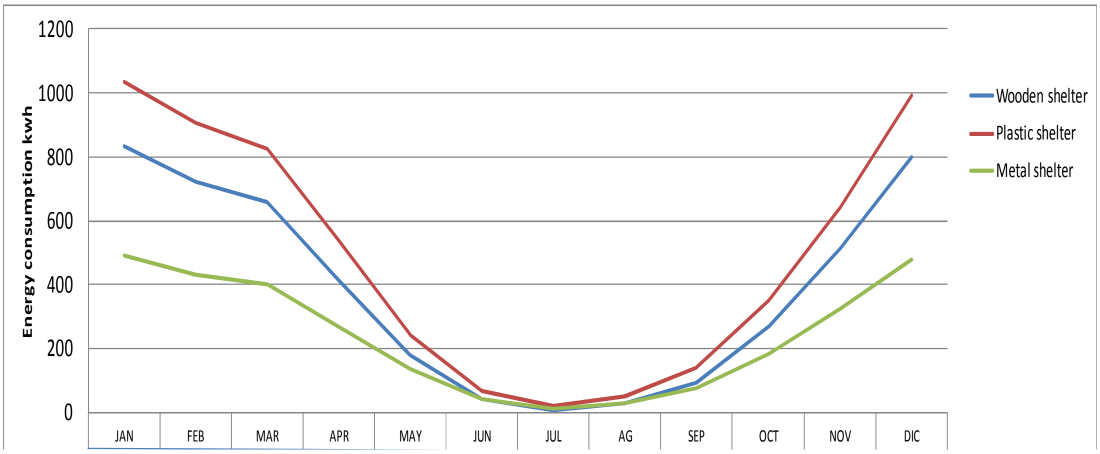

Figure 5.14: Comparison of annual average energy consumption for case studies in five climatic zones of Turkey.

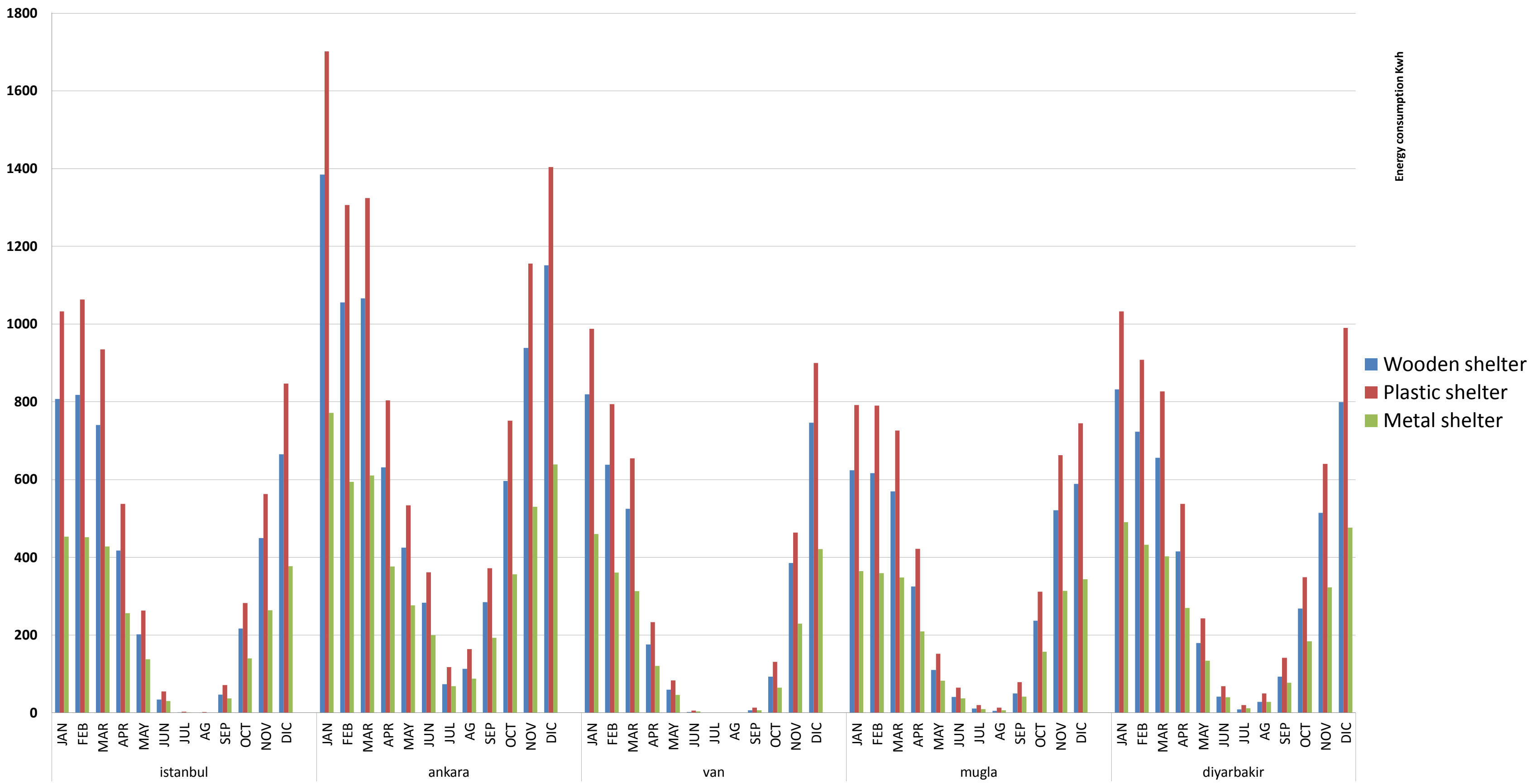

Figure 5.15: Summary graph of annual energy consumption for 3 emergency shelters in five climatic zones of Turkey

From the results of the energy consumption simulation shown from Figures 5.9 to 5.13(numerical tables can be found in the Appendices), the comparative Figure 5.13 and the summary in Figure 5.15 it can be inferred that:

– Maximum heating consumption between the three emergency shelters corresponds to the plastic shelter in all the climatic zones. The small thickness and negligible isolation that this material provides justifies these results. Thus this material is the less appropriate from an energy efficiency point of view to use in the construction of a shelter. Taking into account that in general plastic tents are the main solution for emergency shelters in the aftermath of a disaster, the research of an improvement of the energy efficiency in emergency shelters appears justified.

– Metal shelter presents the best result(less energy consumed) between the three shelters. The isolation of the panel sandwich justifies these results. The use of natural and sustainable isolation will dramatically improve the energy performance of the emergency shelter.

6. CONCLUSIONS AND RECOMMENDATIONS

Natural and human disasters are a constant threaten that causes every year great loss of lives and economic losses. With increasing population, the world's exposure to natural hazards is inevitably increasing, as well as the energy consumption. Energy consumption by use of fossil fuels releases Co2 emissions into the atmosphere intensifying the natural greenhouse effect and causing global warming. Among the polluter agents, buildings are the most damaging polluters on the planet, consuming over half of all the energy used in developed countries and producing over half of all climate-change gases

But, despite of the need of reducing energy use and CO2 emissions, usually post-disaster situations are solved with inadequate and inefficient solutions that cannot cover the basic shelter needs. These solutions are not an adequate architectural response as generally they don't meet basic environmental and sustainable premises.

This performed study represents a preliminary analysis about the influencing factors to develop sustainable emergency shelters that make an efficient use of energy and less hazardous impact to the environment. On one hand, climatic factors of the disaster region where the shelter will be used must be considered and incorporated into the design. On the other hand, sustainable criteria must be involved in the design, construction and upgrading of the shelters. This thesis represents a basis to a further line of investigation towards a better assessment for the improvement of the energy efficiency of this type of architecture.

Through the simulation and analysis of three emergency shelters in different climatic zones of Turkey it is possible to obtain data of the energy performance of different typical envelopes. A local understanding and adaptation of prototypical emergency shelters is possible in order to obtain more efficient emergency shelters. Furthermore, an approach to a new green rating system focused on emergency shelters is proposed and applied to this case study post-disaster housing to check their strengths and weaknesses in different fields of sustainability.

Through the proposed approach to a new green rating system it is observed that the wooden shelter has better sustainable behavior than the plastic and metal shelters. This reinforces the importance of the use of local materials rather than import materials or use pre-fabricated systems. The green rating system also highlights the lack of use of renewable energies in current emergency shelters. Through the design and incorporation of some clean energy systems (solar energy or wind energy for example) the energy consumption can dramatically drop as well as the CO2 emissions. If the design is anticipated to be reused, the initial investment of the incorporation of renewable energies can be easily achieved. Furthermore, regarding the price it can be observed a considerable difference between the locally constructed wooden shelter ($375-$500) and the imported and prefabricated plastic and metal shelters ($4500 and $5800 respectively). This shows that a locally produced shelter, adapted to the specific characteristics of the disaster region, can be more sustainable from the economical and ecological point of view.

Through the energy simulation of the emergency shelters it is shown that the metal shelter has a better energy behavior and less energy consumption while the plastic shelter has the worst energy behavior and the biggest energy consumption. This is due to the isolation incorporated in the sandwich panels of the metal shelter and the lack of isolation in the plastic shelter. This fact reinforces the importance of the use of a natural and sustainable isolation in the shelters(with the thickness and type of material adapted to the local characteristics of the area affected by a disaster) and the need to have a wider range of materials rather than the most commonly used plastic for emergency tents, that this study proves to be insufficient.

None of the emergency shelters is by itself a complete adequate energy efficient and sustainable solution. On an hypothetical disaster situation, under the light of the results of this study, the selection of a solution for an emergency shelter should be chosen taking into account the factors analyzed and the results obtained. The emergency shelter used should apply with the maximum points of the approach for a new green rating system. It also should have a low cost that makes affordable a large production of them. And finally, the emergency shelter should incorporate and improve the strong aspects of energy efficiency of each of them. By applying this aspects, the emergency shelter designed and/or used will be in the proper direction of the energy efficiency and sustainability.

Further points of action in this direction for post-disaster emergency housing should be:

- Further energy simulations of new typologies of emergency shelters.

- To check the green rating checklist with real emergency shelters in their local sites and get feedback.
- To diagnose the existing disaster shelter planning to introduce sustainable strategies and a more energy efficient approach to post disaster-housing.
- To develop an integrated evaluation indicator system for post disaster housing with the inputs of the different agents involved (governments, humanitarian organizations, architects and people affected).

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APPENDICES

APPENDIX A.1: Monthly numerical results for wooden emergency shelters in five climatic zones of Turkey

APPENDIX A.2: Monthly numerical results for plastic emergency shelters in five climatic zones of Turkey

APPENDIX A.3: Monthly numerical results for metal emergency shelters in five climatic zones of Turkey

APPENDIX A.4: Monthly numerical results of heating energy consumption for emergency shelters in five climatic zones of Turkey

Table A.1: Monthly results for wooden emergency shelter in Istanbul.

Month	Operative Temperature (ºC)	External Infiltration (kWh)	Heat Gain (kWh)
January	8.78	-24.86	31.99
February	8.27	-24.85	36.52
March	11.11	-30.32	57.26
April	16.72	-32.96	80.43
May	21.40	-32.42	105.29
June	26.02	-31.30	115.20
July	27.71	-26.55	123.55
August	27.51	-24.35	108.87
September	24.38	-26.15	88.75
October	19.20	-21.70	56.79
November	13.60	-17.89	35.18
December	10.06	-18.58	25.45

Table A.2: Monthly results for wooden emergency shelter in Ankara.

Month	Operative Temperature (ºC)	External Infiltration (kWh)	Heat Gain (kWh)
January	2.59	-36.63	33.35
February	6.11	-36.09	49.44
March	8.17	-39.40	67.58
April	14.24	-35.25	83.79
May	19.11	-36.62	105.71
June	22.70	-36.55	121.41
July	27.18	-36.80	135.58
August	26.14	-33.13	124.62
September	22.27	-33.92	100.19
October	14.59	-30.12	63.56
November	7.74	-27.85	37.76
December	4.35	-26.23	24.05

Table A.3: Monthly results for wooden emergency shelter in Van.

Month	Operative Temperature (ºC)	External Infiltration (kWh)	Heat Gain (kWh)
January	8.38	-21.95	27.74
February	10.80	-24.10	40.53
March	15.03	-32.78	81.75
April	22.58	-33.19	111.98
May	28.36	-38.67	150.89
June	32.79	-36.20	161.41
July	37.18	-29.60	162.64
August	35.03	-27.88	141.44
September	29.67	-23.77	101.90
October	23.23	-21.45	69.22
November	15.26	-17.12	36.94
December	9.04	-18.66	24.43

Table A.4: Monthly results for wooden emergency shelter in Mugla.

Month	Operative Temperature (ºC)	External Infiltration (kWh)	Heat Gain (kWh)
January	12.37	-27.98	44.66
February	12.33	-28.53	53.70
March	15.71	-38.90	87.95
April	18.88	-33.05	92.76
May	25.55	-33.73	119.50
June	28.84	-30.97	132.85
July	29.34	-25.75	135.21
August	29.12	-27.51	124.09
September	27.15	-29.65	105.56
October	20.61	-28.38	77.34
November	14.98	-27.51	50.55
December	12.30	-21.01	34.37

Table A.5: Monthly results for wooden emergency shelter in Diyarbakir.

Month	Operative Temperature (ºC)	External Infiltration (kWh)	Heat Gain (kWh)
January	11.76	-39.81	58.31
February	13.34	-38.36	69.17
March	16.33	-44.43	101.34
April	20.51	-38.90	115.72
May	26.38	-36.51	131.63
June	29.01	-29.27	140.66
July	30.56	-28.29	144.53
August	30.61	-29.06	134.57
September	28.34	-32.56	115.75
October	23.11	-37.97	99.64
November	17.19	-34.37	66.26
December	12.68	-38.05	58.61

APPENDIX A.2

Table A.6: Monthly results for plastic emergency shelter in Istanbul.

Month	Operative Temperature (ºC)	External Infiltration (kWh)	Heat Gain (kWh)
January	7.99	-20.08	31.99
February	7.47	-20.72	36.52
March	10.33	-26.55	57.26
April	16.03	-30.94	80.43
May	20.85	-33.98	105.29
June	25.67	-32.68	115.20
July	27.48	-28.40	123.55
August	27.29	-25.98	108.87
September	24.05	-26.56	88.75
October	18.81	-20.61	56.79
November	13.06	-14.99	35.18
December	9.45	-14.81	25.45

Table A.7: Monthly results for plastic emergency shelter in Ankara.

Month	Operative Temperature (ºC)	External Infiltration (kWh)	Heat Gain (kWh)
January	1.51	-30.86	33.35
February	5.12	-32.11	49.44
March	7.20	-35.45	67.58
April	13.46	-33.09	83.79
May	18.54	-36.39	105.71
June	22.20	-37.29	121.41
July	26.86	-39.31	135.58
August	25.79	-34.72	124.62
September	21.81	-34.34	100.19
October	13.93	-27.89	63.56
November	6.91	-23.78	37.76
December	3.49	-21.37	24.05

Table A.8: Monthly results for plastic emergency shelter in Van.

Month	Operative Temperature (ºC)	External Infiltration (kWh)	Heat Gain (kWh)
January	7.71	-18.47	27.74
February	10.07	-21.27	40.53
March	14.30	-30.73	81.75
April	22.06	-33.55	111.98
May	28.06	-41.90	150.89
June	32.71	-41.12	161.41
July	37.33	-35.60	162.64
August	35.11	-32.80	141.44
September	29.56	-26.22	101.90
October	22.93	-21.49	69.22
November	14.78	-15.01	36.94
December	8.42	-15.21	24.43

Table A.9: Monthly results for plastic emergency shelter in Mugla.

Month	Operative Temperature (ºC)	External Infiltration (kWh)	Heat Gain (kWh)
January	11.69	-24.60	44.66
February	11.59	-25.42	53.70
March	14.99	-36.67	87.95
April	18.30	-32.02	92.76
May	25.21	-35.30	119.50
June	28.64	-33.92	132.85
July	29.17	-28.42	135.21
August	28.97	-30.26	124.09
September	26.89	-31.27	105.56
October	20.15	-27.46	77.34
November	14.36	-24.86	50.55
December	11.70	-17.59	34.37

Table A.10: Monthly results for plastic emergency shelter in Diyarbakir.

Month	Operative Temperature (ºC)	External Infiltration (kWh)	Heat Gain (kWh)
January	10.95	-39.64	58.31
February	12.49	-35.91	69.17
March	15.57	-43.17	101.34
April	19.88	-38.62	115.72
May	26.08	-38.92	131.63
June	28.83	-32.29	140.66
July	30.51	-32.29	144.53
August	30.61	-33.42	134.57
September	28.16	-35.39	115.75
October	22.62	-38.28	99.64
November	16.59	-33.12	66.26
December	11.88	-35.08	58.61

APPENDIX A.3

Table A.11: Monthly results for metal emergency shelter in Istanbul.

Month	Operative Temperature (ºC)	External Infiltration (kWh)	Heat Gain (kWh)
January	11.71	-50.79	59.33
February	11.35	-49.78	53.11
March	12.82	-47.08	65.53
April	15.96	-31.00	74.15
May	18.48	-16.21	69.85
June	20.99	1.61	65.87
July	22.21	11.17	70.31
August	22.32	11.44	82.17
September	20.69	-2.07	97.16
October	17.93	-14.49	85.50
November	14.65	-27.78	60.51
December	12.56	-40.39	41.44

Table A.12: Monthly results for metal emergency shelter in Ankara.

Month	Operative Temperature (ºC)	External Infiltration (kWh)	Heat Gain (kWh)
January	7.67	-78.18	58.60
February	9.75	-63.50	80.19
March	10.76	-62.17	69.72
April	14.27	-39.16	71.03
May	16.89	-25.34	69.01
June	18.72	-14.44	64.18
July	21.33	-1.51	73.37
August	21.03	-2.28	87.47
September	19.10	-16.39	111.05
October	14.82	-34.97	87.59
November	10.88	-52.55	62.86
December	8.87	-62.25	37.68

Table A.13: Monthly results for metal emergency shelter in Van.

Month	Operative Temperature (ºC)	External Infiltration (kWh)	Heat Gain (kWh)
January	11.45	-45.41	70.37
February	12.83	-38.99	77.08
March	15.07	-36.24	97.41
April	19.15	-14.64	90.44
May	21.89	-0.56	80.79
June	24.22	13.23	72.67
July	26.73	33.20	78.29
August	25.78	28.25	89.27
September	23.34	13.48	105.34
October	20.14	-3.15	115.05
November	15.64	-21.35	84.96
December	11.90	-40.27	62.59

Table A.14: Monthly results for metal emergency shelter in Mugla.

Month	Operative Temperature (ºC)	External Infiltration (kWh)	Heat Gain (kWh)
January	13.86	-42.19	86.77
February	13.77	-41.41	84.67
March	15.39	-40.23	98.73
April	17.17	-23.93	74.47
May	20.69	-1.07	68.67
June	22.38	11.87	60.40
July	22.97	18.16	66.32
August	22.96	15.00	86.50
September	22.08	3.86	114.42
October	18.64	-16.31	110.96
November	15.42	-33.39	102.89
December	13.93	-35.95	66.84

Table A.15: Monthly results for metal emergency shelter in Diyarbakir.

Month	Operative Temperature (ºC)	External Infiltration (kWh)	Heat Gain (kWh)
January	13.18	-53.91	111.55
February	13.93	-45.48	103.40
March	15.49	-42.77	109.48
April	17.68	-23.41	80.08
May	20.75	-1.13	60.20
June	22.33	11.87	49.17
July	23.26	18.17	52.97
August	23.40	16.88	71.25
September	22.38	3.92	107.40
October	19.70	-17.62	135.82
November	16.44	-32.36	121.93
December	13.72	-49.17	118.99

APPENDIX A.4

Table A.16: Monthly results of heating energy consumption for emergency shelter in Istanbul.

Month	Wooden shelter	Plastic shelter	Metal shelter
January	807.41	1033.22	453.29
February	818.16	1063.29	451.45
March	740.34	934.87	427.97
April	417.82	537.61	256.22
May	202.15	263.17	137.45
June	34.51	54.65	30.97
July	1.59	3	1.30
August	0.66	2.28	0.95
September	46.68	71.47	36.96
October	217.38	282.01	140.06
November	449.69	562.75	263.99
December	664.62	846.88	377.31

Table A.17: Monthly results of heating energy consumption for emergency shelter in Ankara.

Month	Wooden shelter	Plastic shelter	Metal shelter
January	1384.39	1701.66	771.29
February	1055.75	1306.81	593.84
March	1066.48	1324.42	610.86
April	631.19	803.71	376.33
May	424.83	533.41	276.53
June	283.21	361.13	199.47
July	78.04	117.44	68.35
August	113.38	164.23	88.25
September	284.70	371.90	192.80
October	596.28	751.52	355.83
November	938.58	1155.69	529.96
December	1151.32	1404.22	639.11

Table A.18: Monthly results of heating energy consumption for emergency shelter in Van.

Month	Wooden shelter	Plastic shelter	Metal shelter
January	819.33	988.08	460.24
February	638.58	794.13	360.80
March	525.13	654.28	312.81
April	175.99	233.73	120.72
May	59.49	83.43	46.22
June	2.14	5.97	3.68
July	0	0	0
August	0	0	0
September	6.30	13.15	6.55
October	93.10	131.46	64.92
November	385.18	464.09	229.80
December	746.23	900.04	420.81

Table A.19: Monthly results of heating energy consumption for emergency shelter in Mugla.

Month	Wooden shelter	Plastic shelter	Metal shelter
January	623.70	721.94	364.35
February	616.66	790.33	359.25
March	569.61	725.98	348.25
April	325.42	422.21	209.27
May	109.84	152.06	82.84
June	41.20	64.84	37.30
July	10.89	19.82	10.01
August	5.19	12.89	6.83
September	49.53	78.95	41.49
October	237.09	312.14	157.46
November	521.27	663.10	313.82
December	588.89	745.01	343.69

Table A.20: Monthly results of heating energy consumption for emergency shelter in Diyarbakir.

Month	Wooden shelter	Plastic shelter	Metal shelter
January	831.87	1032.87	490.44
February	723.26	908.28	432.15
March	656.36	826.48	402.77
April	415.53	537.58	270.24
May	179.66	243.16	134.25
June	41.34	68.38	40.37
July	8.87	19.85	11.82
August	28.58	49.94	28.86
September	93.02	141.39	77.16
October	268.32	348.93	183.85
November	514.37	640.24	322.53
December	799.19	989.97	476.02

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